BBC

55TH ANNIVERSARY: THE FIRST SPACE WALK

The thrilling tale of Soviet Space Race success

#178 MARCH 2020

Sky at Night

THE UK'S BEST SELLING ASTRONOMY MAGAZINE

DISCOVER EARTH'S SATELLITE

A NEW SIDE TO THE MOON

Become a lunar pioneer with our expert observing guide

VENUS AT TWILIGHT

Watch the Evening Star's stunning display all month

DARK MATERIALS

In search of shadow nebulae

LAUNCH MANIFEST

Europe's missions in the coming decade

THREE'S A CROWD

The unusual orbits of triple star systems

MADE OF STAR STUFF

Our supernova origins in amazing new detail


Sky-Watcher®
Be amazed.
ED APOCHROMATIC REFRACTORS
ED OPTICS
Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 161 October 2018
OTA reviewed
EVOSTAR™ DS-PRO ED APO DOUBLETS
ED OPTICS
EVOSTAR-72ED DS-PRO
72mm f/ 5.8 OTA
Code: 10201
SRP £315
Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 158 JULY 2018
EVOSTAR-80ED DS-PRO
80mm f/7.5 OTA
Code: 10202
SRP £579
"Great all-round package…Overall this telescope packs a lot of punch…a complete setup with lovely crisp optics"
BBC SKY AT NIGHT MAGAZINE
SRP £1719
SRP of OTA only
EVOSTAR-150ED DS-PRO
150mm f/8 OTA
Code: 10198
SYNSCAN GO-TO
SRP £1429
EQ6-R PRO SYNSCAN MOUNT
SRP of Mount only
Code 20855
EVOSTAR-100ED DS-PRO
100mm f/9 OTA
Code: 10203
SRP £899
Sky at Night MAGAZINE GROUP TEST WINNER
Awarded to Evostar-100ED (previous single-speed version) Group test: 4-inch Apochromatic Refractors under £3000
EVOSTAR-120ED DS-PRO
120mm f/7.5 OTA
Code: 10204
SRP £1349
0.85x FOCAL REDUCERS/CORRECTORS FOR EVOSTAR ED DS-PRO
Require M48x0.75 DSLR Adaptor – Canon and Nikon Adaptors available at £19.99 SRP
For Evostar-72ED Code 20232
For Evostar-80ED Code 20236
For Evostar-100ED Code 20235
For Evostar-120ED Code 20234
For Evostar-150ED Code 20321
SRP £199
ESPRIT™ PROFESSIONAL SUPER APO TRIPLETS
ED OPTICS
ESPRIT-80ED
80mm f/5 OTA
Code: 10243
SRP £1149
SRP £2419
SRP £1749
ESPRIT FIELD FLATTENERS
Require M48x0.75 DSLR Adaptor – Canon & Nikon Adaptors available at £19.99 SRP
For Esprit-80ED Code: 20187 SRP £139
For Esprit-100ED Code: 20188 SRP £179
For Esprit-120ED Code: 20189 SRP £225
For Esprit-150ED Code: 20190 SRP £265
"In short, the Esprit provided first-class optical performance visually and photographically…The Esprit-120's performance matches the best in the business at a competitive price"
SKYNEWS MAGAZINE REVIEW BY ALAN DYER
ESPRIT-120ED
120mm f/7 OTA Code: 10233
ESPRIT-100ED
100mm f/5 OTA Code: 10244
Sky at Night MAGAZINE ★★★★★ REVIEWED IN Issue 109 June 2014
"Star images were excellent across the full width of the sensor…The optics feature a high level of correction across the field and star images through all filters were tight and consistent thanks to its superb colour correction."
ASTRONOMY NOW MAGAZINE REVIEW BY NIK SZYMANEK
ESPRIT-150ED
150mm f/7 OTA
Code: 10234
SRP £4699
Sky-Watcher ESPRIT 150ED
THE ESSENTIAL Optical Product Guide
DISCOVER NEW IMAGING HORIZONS
Email for 88 Page FREE Catalogue
OVL
Available from dealers throughout the UK
OPTICAL VISION LIMITED
Full product details at:
www.opticalvision.co.uk
info@opticalvision.co.uk

THE BIRTH OF TRULY BEAUTIFUL ASTROPHOTOGRAPHY

Photo: Philipp Keltenich Taken with: Pro APO 71/450 Quadruplet

The beauty of excellent astrophotography is admired by everyone. Would you like to become one of the astrophotographers who create such images? You too can make this dream a reality with an Omegon premium apochromat, featuring an outstanding ED doublet, triplet or quadruplet lens and employing FPL-53 glass. With super-flat image fields and pin-sharp stars right up to the edge of the image. Of course the precision mechanics of the CNC-machined OTA are also impressive: all focusers are precision rack-and-pinion focusers with a high load capacity and 360° rotation for optimum image capture. This is the start of better astrophotography.

Pro APO Doublet

- Perfect for entering the world of premium apos
- A twin-element ED doublet objective: for a crystal clear image and great colour correction
- Discover the advantages of good doublet apos: finer details in planetary observing and astrophotos with dreamlike sharpness

Pro APO Triplet

- Even at higher magnification, pure colour and crystal clear images
- A fully-apochromatic objective corrects the image, with its three lens elements, so cleverly that you will not notice any blue fringes even on bright stars

Pro APO Quadruplet: for full-frame cameras

- The optics of the four-lens quadruplet offer fully-apochromatic imaging
- Effective flat-field image field correction with a huge 44mm image circle
- From now on your images can remain in their original size without having to crop them off at the edges
- Your astrophotos will look as sharp and true in colour as with the triplet, but also show wonderful pin-point stars right out to the edges of the image
- Look forward to observations and images that will remain in your memory

	Article No.	Aperture	Design	Focuser	Price in £
Pro APO 60/330 Doublet OTA					
Weight 1.7 kg | 3.7 lbs	60852	60mm f/5.5	doublet ED	2″ focuser with 1:10 reduction	549
Pro APO 72/400 Doublet OTA					
Weight 2.0 kg | 4.4 lbs	60853	72mm f/5.6	doublet ED	2″ focuser with 1:10 reduction	539
Pro APO 71/450 Quadruplet OTA					
Weight 2.5 kg | 5.5 lbs	60855	71mm f/6.3	quadruplet ED	2.5″ focuser with 1:10 reduction	629
Pro APO 80/500 Triplet OTA					
Weight 3.7 kg | 8.2 lbs	60856	80mm f/6.3	triplet ED	2.5″ focuser with 1:10 reduction	989
Pro APO 80/500 Triplet Carbon OTA					
Weight 3.4 kg | 7.5 lbs	60857	80mm f/6.3	triplet ED	2.5″ focuser with 1:10 reduction	1019
Pro APO 90/600 Triplet OTA					
Weight 3.8 kg | 8.4 lbs	60858	90mm f/6.7	triplet ED	2.5″ focuser with 1:10 reduction	1019
Pro APO 107/700 Triplet OTA					
Weight 6.0 kg | 13.3 lbs	60859	107mm f/6.5	triplet ED	3″ focuser with 1:10 reduction	1719

Welcome

Get to know the Moon in more detail than ever before

With the Moon already high in the sky as twilight falls, this month is a great time to see a new side to it and to marvel at the rich landscapes of pitted lava plains and rugged mountain peaks that telescopes reveal at every phase other than full. This month Pete Lawrence is your guide to doing more with your lunar observations, from using the Moon's own version of latitude and longitude to the spectacle of occultations, when background objects slip behind its disc. Read the article on page 37.

The second half of the month sees the Moon's new phase, when lunar light recedes from the night sky, the perfect time for our feature all about dark nebulae. Caches of antimatter these are not, rather these intriguing lanes of interstellar dust reveal themselves through the telescope as silhouettes set against a background star field. Turn to page 61 to read Will Gater's fascinating feature about where to find them and how best to observe them.

The Moon features prominently in the European Space Agency's plans for the next decade, covered in our feature on page 67. Its aim to build elements of NASA's Lunar Gateway – a space station in orbit around the Moon – received ratification at the end of last year by ESA member states, at a meeting which set the organisation's agenda for the next decade and beyond. Elizabeth Pearson takes a detailed look at which missions received a share of the record levels of funding that were allocated, and the UK's post-Brexit place in the European exploration of space.

Enjoy the issue!

Chris Bramley, Editor

PS Our next issue goes on sale on Wednesday 26 March, and don't forget British Summer Time begins this month: at 1am on Sunday 29 March the clocks go forward one hour.

HOW TO CONTACT US

Subscriptions, binders and back issues
03330 162119*
Mon–Fri 8am–6pm; Sat 9am–1pm

*Calls from landlines will cost up to 9p per minute. Call charges from mobile phones will cost between 3p and 55p per minute but are included in free call packages. If calling from overseas, please dial +44 (0)1604 973727

Editorial enquiries
+44 (0)117 300 8754
9.30am–5.30pm, Mon–Fri

Advertising enquiries
+44 (0)117 300 8145

Print subscription enquiries
bbcskyatnight@buysubscriptions.com

Digital subscription enquiries
bbcskyatnightdigital@buysubscriptions.com

Editorial enquiries
contactus@skyatnightmagazine.com

Subscription enquiries
UK enquiries: FREEPOST IMMEDIATE MEDIA (please write in capitals)
Overseas enquiries: PO Box 3320, 3 Queensbridge, Northampton NN4 7BF, UK

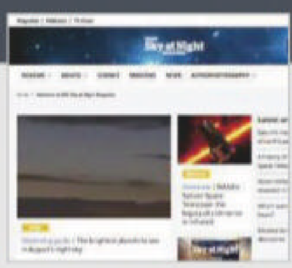
Editorial enquiries
BBC Sky at Night Magazine, Immediate Media Co Bristol Ltd, Eagle House, Colston Avenue, Bristol BS1 4ST

Become an Insider

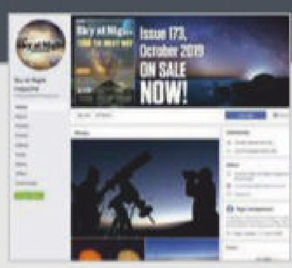
The more we know about what you like, the better placed we are to bring you the best magazine possible. So we'd like to invite you to join our online reader panel 'Insiders'. Just log on to **www.immediateinsiders.com/register** to fill out the short registration survey and we'll be in touch from time to time to ask for your opinions on the magazine and other relevant issues.

Sky at Night – lots of ways to enjoy the night sky...

Television
Find out what *The Sky at Night* team have been exploring in recent and past episodes on page 18



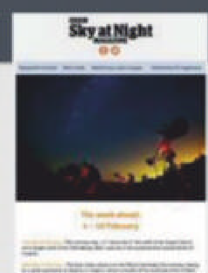
Online
Visit our website for competitions, astrophoto galleries, observing guides and more



Social Media
All the details of our latest issue on Twitter and Facebook, plus website and news updates

Podcasts
Listen to our Radio Astronomy podcasts where the magazine team and guests discuss astro news

Tablet/phone
Get each month's issue on your Apple or Android device, now with bonus image galleries



eNewsletter
The best targets to observe each week, delivered to your inbox. Visit **bit.ly/skynewsletter**

Find out more at: www.skyatnightmagazine.com

CONTENTS

C = on the cover

Features

Regulars

Astrophotography

Reviews

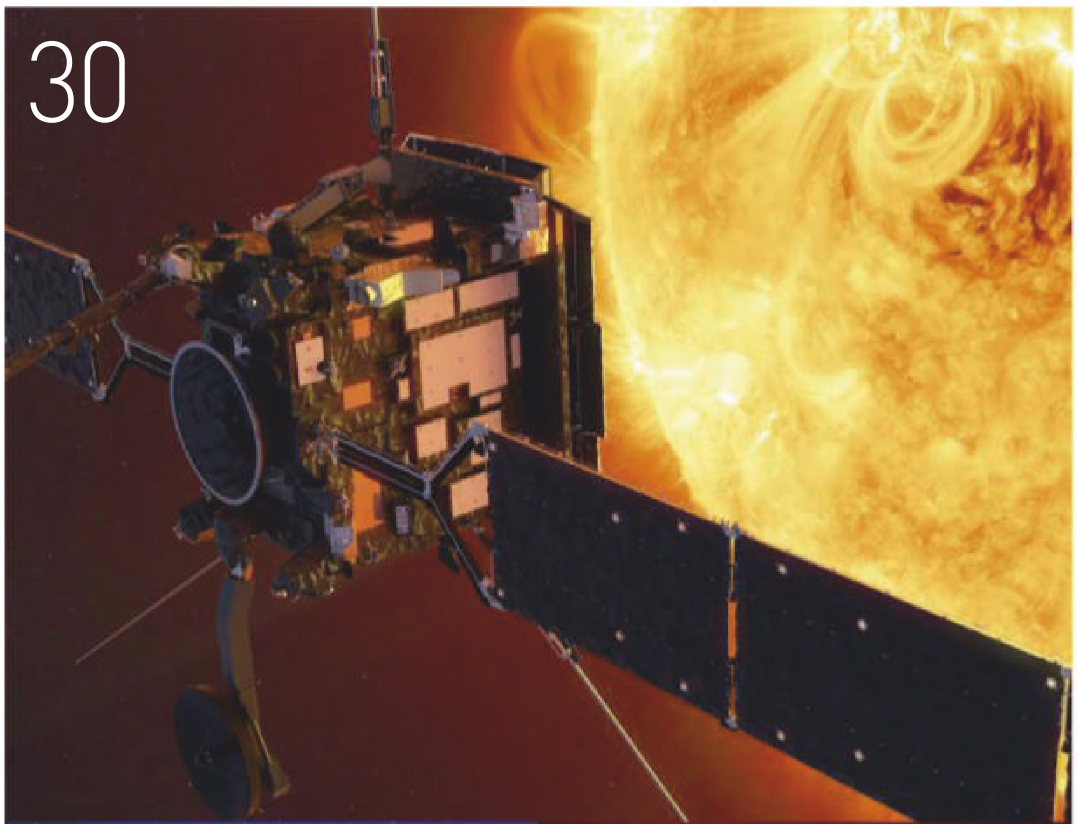
16-PAGE CENTRE PULLOUT

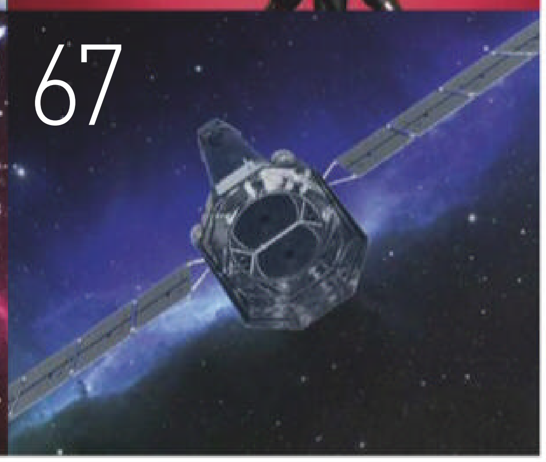
The Sky Guide

COVER MAIN IMAGE: PETE LAWRENCE. THIS PAGE: PETE LAWRENCE, ESA/ATG MEDIALAB, RYKOFF COLLECTION/CORBIS/CORBIS VIA GETTY IMAGES, @THESHED_PHOTOSTUDIO, WILL GATER, ESA, BBC

New to astronomy?

To get started, check out our guides and glossary at
www.skyatnightmagazine.com/astronomy-for-beginners





This month's contributors

Michael Lachmann

Producer and author

"It's not easy flying close to the Sun. Discovering how the Solar Orbiter engineers have solved those problems using technology from unexpected sources has been a treat." **Michael looks at the Solar Orbiter mission, page 30**

Elizabeth Pearson

News editor

"The nations of Europe have been making giant leaps in terms of space operations – looking out at the cosmos and down on Earth – and ESA is set to continue for years." **Elizabeth finds out about ESA's plans in the next decade, page 67**

Nisha Beerjeraz-Hoyle

Astronomy writer

"It was an immense pleasure to recount Alexei Leonov's first spacewalk – a truly remarkable moment in space history and a wonderfully vivid tale." **Nisha chronicles the first spacewalk, page 72**

Extra content ONLINE

Visit **www.skyatnightmagazine.com/bonus-content/ZLC27GC/** to access this month's selection of exclusive Bonus Content

MARCH HIGHLIGHTS

A beginner's guide to astronomy

Watch the January episode of *The Sky at Night*, in which the team reveal their top stargazing tips.

Interview: how to weigh an exoplanet

Astronomer Jason Wright reveals how NASA's NEID instrument will measure the masses of planets orbiting distant stars.

Black Holes: A Very Short Introduction

Confused about black holes? Listen to chapters from an audiobook that explains the basics of black hole science.

The Virtual Planetarium

Pete Lawrence and Paul Abel guide us through the best sights to see in the night sky this month.

NASA/ESA AND B. HOLWERDA (UNIVERSITY OF LOUISVILLE)

Gentle GIANT

Enormous galaxy UGC 2885 is 2.5 times the diameter of the Milky Way and home to 10 times as many stars

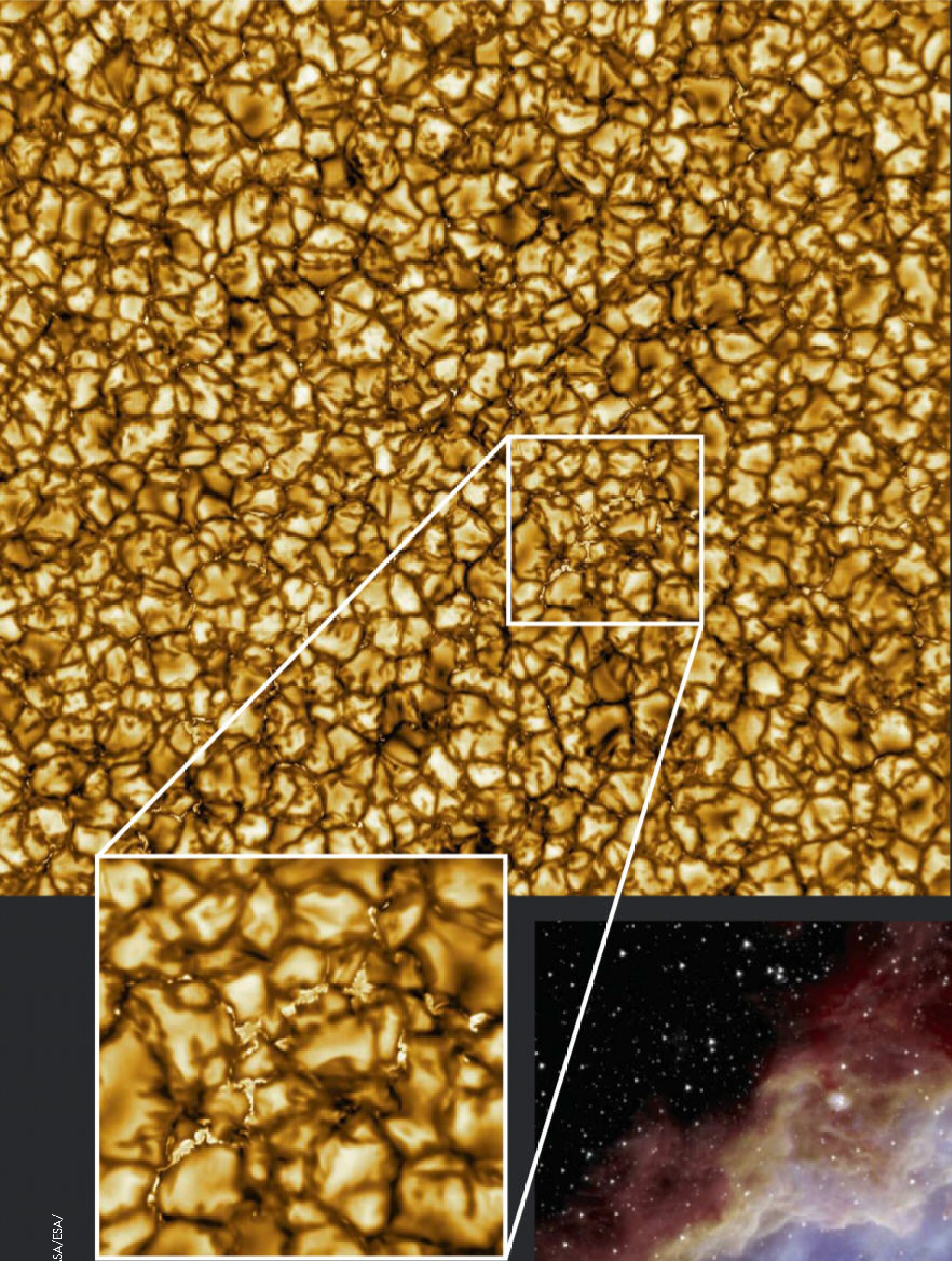
HUBBLE SPACE TELESCOPE, 5 JANUARY 2020

It may be the largest galaxy in our local Universe, but UGC 2885 isn't throwing its weight about. Sitting quietly in a vacant area in Perseus, its beautifully intact disk suggests peaceful millennia have passed without it consuming smaller nearby galaxies or colliding with them.

Benne Holwerda of the University of Louisville, Kentucky, who observed the giant with the Hubble Space Telescope, has dubbed it Rubin's Galaxy, in honour of pioneering American astronomer Vera Rubin (1928–2016). It was her studies of unusual rotation rates in UGC 2885 and other galaxies that pointed to the existence of something invisible at play, an unseen substance with a gravitational influence – dark matter.

Rubin's Galaxy contains a trillion stars, although the bright star blazing near the centre of this picture isn't one of them. This is a foreground star located 232 million lightyears closer to Earth.

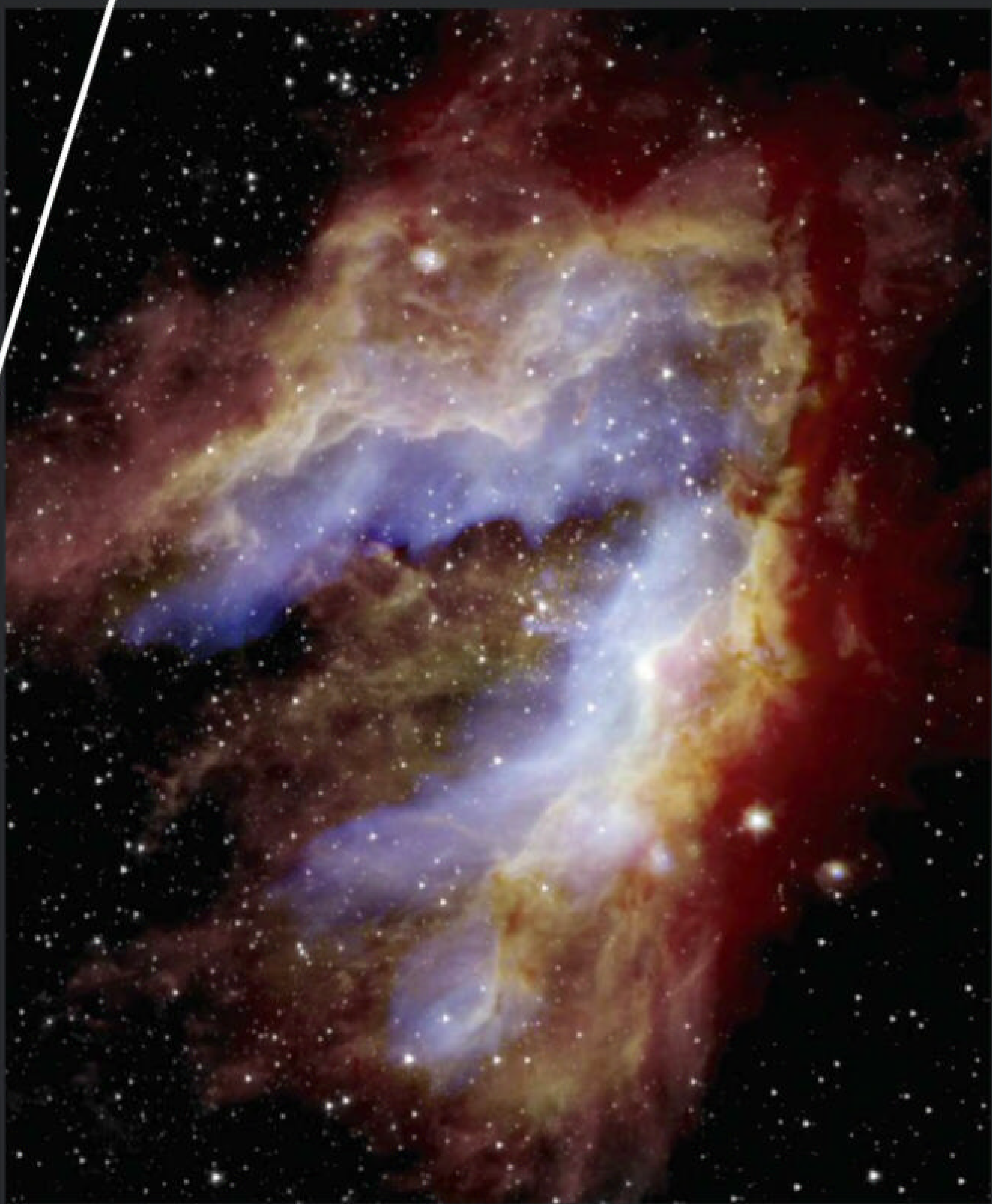
MORE ONLINE
A gallery of these and more stunning space images



◁ Seeing the Sun like never before

DANIEL K. INOUYE SOLAR TELESCOPE, 29 JANUARY

This, the most detailed view of the Sun ever captured, is the 'first light' image of the National Science Foundation's new solar telescope. It reveals features as small as 30km on the solar surface for the first time. The cell-like structures that fill the telescope's view are a result of convection flows; in each of the cells the Sun's internal heat causes plasma to rise in the centre, before cooling and sinking back down in dark lanes. Within the dark cracks are bright specks (see inset). These are the markers of magnetic fields, which are thought to channel energy into the Sun's outer layer: its corona. This image covers an area 36,500km², and each cell is about three times the surface area of the UK.



How the Swan hatched ▷

SOFIA, HERSCHEL SPACE OBSERVATORY, SPITZER SPACE TELESCOPE, 7 JANUARY 2020

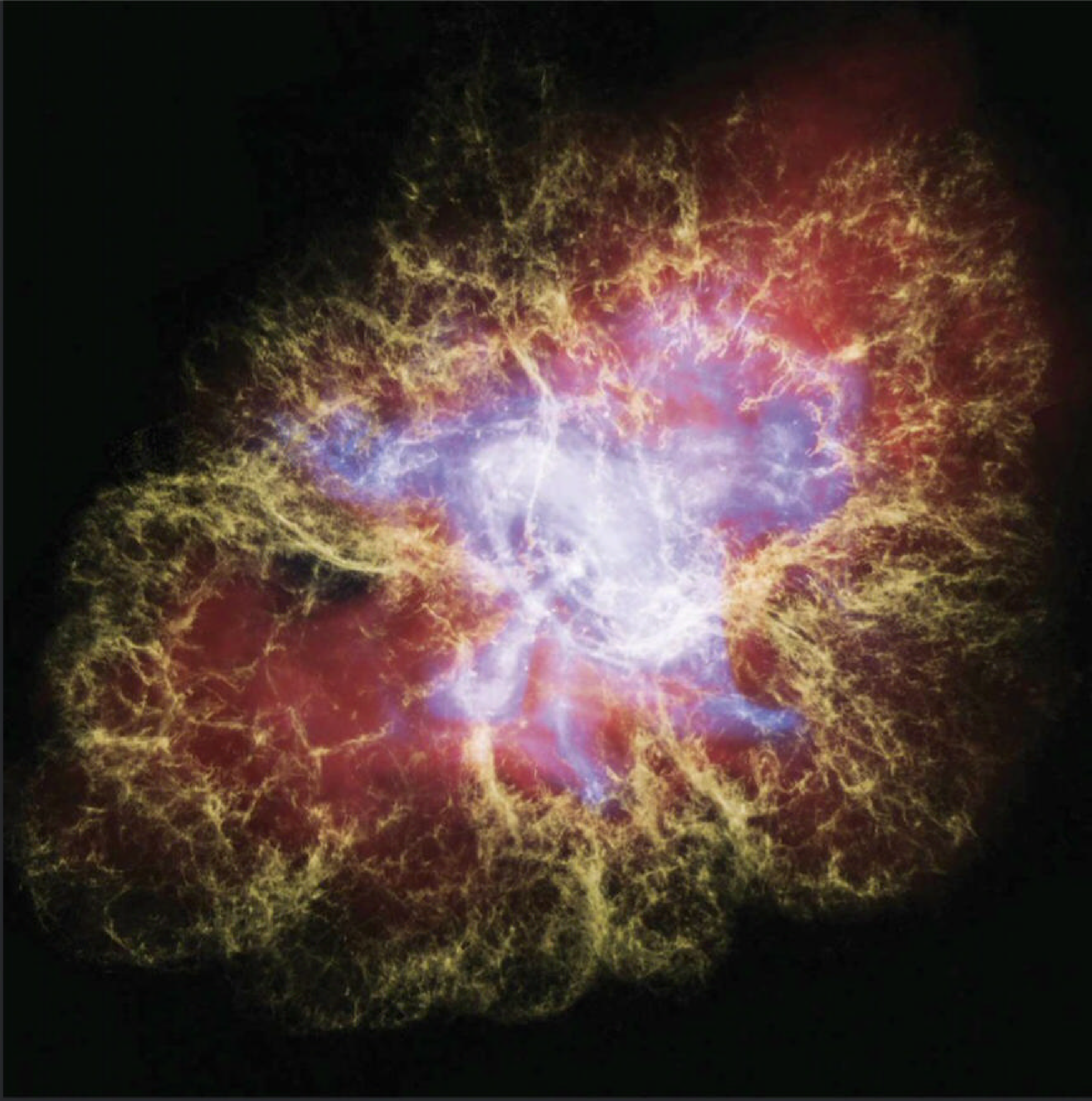
The distinctive curved neck of the Swan (or Omega) Nebula is actually a relatively recent feature, according to new observations from SOFIA (Stratospheric Observatory for Infrared Astronomy), NASA's flying telescope housed in a modified Boeing 747SP. It reveals gas in blue heated by massive stars near the nebula's centre, but also shows dust glowing green, warmed not just by older stars but also newborn stars nearby. These never-before-seen protostars point to a multi-generational back story: with the oldest region at its heart, the northern area formed next and the southern region came most recently.

NSO/AURA/NSF, NASA/SOFIA/DE BUIZER/RADOMSKI/LIM;NASA/JPL-CALTECH; ESA/HERSCHEL, NASA/ESA/STSCI/F.SUMMERS, ET AL; NASA/CXC/SAO/N.WOLK, ET AL, & NASA/CALTECH/IPAC/R.HURT, ESO

A closer look at the Crab ▷

CHANDRA X-RAY OBSERVATORY, HUBBLE SPACE TELESCOPE, SPITZER SPACE TELESCOPE, 5 JANUARY 2020

One of the few objects to emit radiation all across the electromagnetic spectrum, the Crab Nebula is the wreckage of a supernova first observed almost 1,000 years ago. With a rapidly spinning neutron star embedded in its centre, it booms beams of radiation at 30 pulses per second, while around its pulsing heart whirl filaments of gas and debris flung out by the original explosion. NASA visualisation specialists have now combined multi-wavelength data from Chandra, Hubble and Spitzer to create a 3D representation of this energetic nebula. View it at: **bit.ly/youtubecrabnebula**

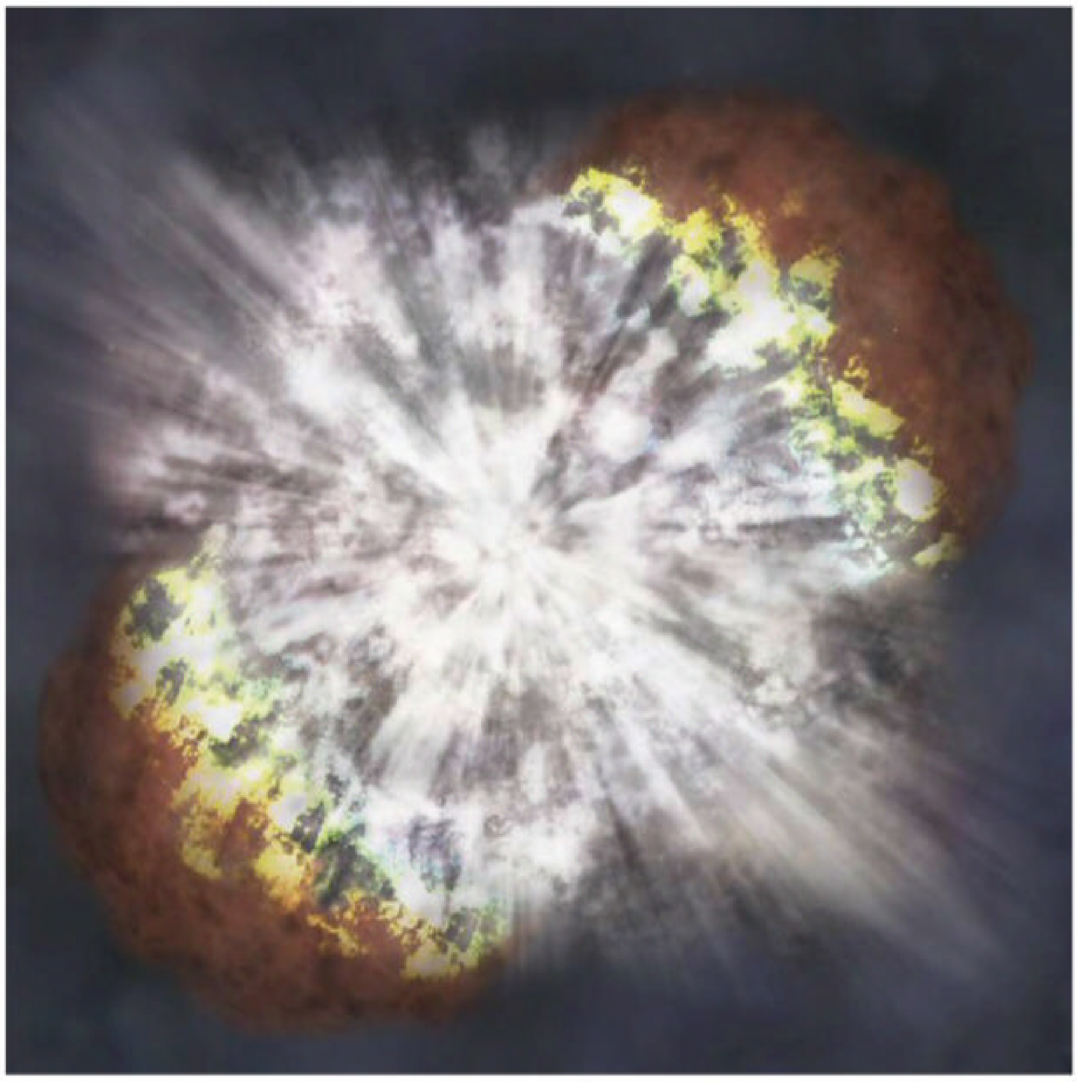


◁ Odd couple

VERY LARGE TELESCOPE, 6 JANUARY 2020

Why does the tidy, compact spiral galaxy NGC 470 on the right look so different to its neighbour NGC 474, a shell elliptical galaxy spreading out vastly and fuzzily in concentric rings of stars? At least 10 per cent of elliptical galaxies in our Universe have this diffuse, shell-like structure, but the reasons are unknown. The shells may be 'ripples' following a merger with a smaller galaxy, or – since spiral galaxies make up around 72 per cent of the galaxies that have been observed – are they overcoming their wispier cousins? It may be that NGC 470 has been exerting a powerful gravitational pull on NGC 474 for millennia, slowly pulling it apart.

BULLETIN



◄ An artist's impression shows the supernova SN2006gy (left), with views captured by the Chandra X-ray (above, top) and Lick Observatories (above, lower)

Brightest stellar explosion caused by colliding stars

The debris left behind indicates an event similar to a Type IA supernova

Over 13 years ago, astronomers saw the brightest supernova ever witnessed, SN2006gy. Now, more than a decade later, a new study might have uncovered the explosion's cause – two stars colliding in a cosmic crash.

Back on 18 September 2006, astronomers from Kyoto University spotted an extremely bright supernova in the galaxy NGC 1260. They took several spectral measurements of the explosion site. These had several lines identifying elements within the cloud, one of which defied explanation, until a recent analysis identified it as neutral iron, with atoms retaining all their electrons.

"This low-energy state of iron is typically not seen in supernovae, where the high energies involved tend to strip one or several electrons from the atoms," says Anders Jerkstrand from the Max Planck Institute for Astrophysics, who led the recent study. "This particular set of lines has never been seen before in any kind of astrophysical nebula. SN 2006gy must truly have some unusual physical properties."

The amount of iron points towards an unusual origin for the explosion – something akin to a Type IA supernova. Usually these are caused by a dense white dwarf reaching critical mass by syphoning stellar material from a companion. Here, however, it appears that a white dwarf actually collided with a red giant's core, causing them to detonate.

"The results are significant in several ways," says Keiichi Maeda from Kyoto University. "The origin of SN 2006gy as a Type IA supernova turns upside down what most researchers have assumed."

https://www.mpia.de/en

Comment

by Chris Lintott

As astronomers have built more sophisticated survey instruments with which to hunt for supernovae and other transient objects, their discovery has become almost commonplace. So it's refreshing to find out that we can still be surprised. SN2006gy was such an unusual event that it's still making waves, 13 years later, and there may be much more to find.

Projects such as the Large Synoptic Survey Telescope are expected to alert us to tens of thousands of transients a night, and the hope is that among them will be whole new categories that go bang. Radio astronomers have had a happy decade trying to understand fast radio bursts; the rest of us might now have our own mysteries to chase.

Chris Lintott co-presents *The Sky at Night*

Aurora hunters: astronomers capture a new shape

Citizen scientists help discover new aurora

Auroral 'dunes' are spotted in images by amateur astronomers

Finnish amateur astronomers have helped identify a new shape of aurora – dunes.

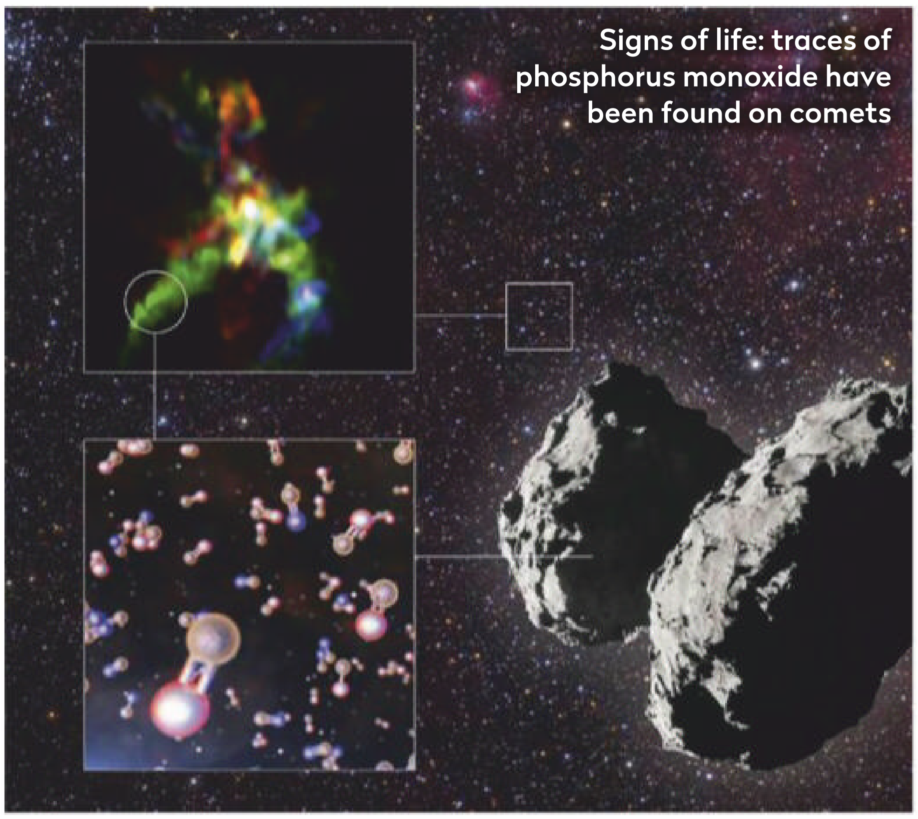
Minna Palmroth, a space weather scientist from the University of Helsinki, was examining the hobbyists' images to classify their features when she discovered dune-like shapes which didn't fit the standard categories.

In late 2018, the astronomers saw the feature again and photographed them from several locations. Using these, Palmroth was able to measure the altitude they occurred at: 100km – in a region called the mesosphere. The atmosphere at this height sometimes forms a cold layer of air which traps the aurora, forming the dunes.

"It was like piecing together a puzzle or conducting detective work," says Matti Helin, one of the aurora hunters who took the photographs. "Every day we found new images and came up with new ideas. Eventually, we got to the bottom of it."

www.helsinki.fi

Comets brought ingredient of life to Earth


Signs of life: traces of phosphorus monoxide have been found on comets

One of the major ingredients of life, phosphorus – which makes up DNA and cell membranes – could have been brought to our planet by comets. A new study used observations from the Atacama Large Millimeter/Submillimeter Array (ALMA) and Rosetta's ROSINA to track the element's journey from the stellar nursery where the Sun was born to modern Earth.

Using ALMA to look at star forming regions, astronomers tracked the element in the form of phosphorus monoxide. This molecule would be present near a newly formed star such as our Sun, but would get 'frozen out' as the system cooled, to become trapped in grains of ice that would form comets.

To find the compound in modern day comets, the team looked at measurements of 67P/Churyumov-Gerasimenko taken by ROSINA's spectrometer, which found clear signs of phosphorous monoxide during its investigations of the comet from 2014-16.

"The combination of the ALMA and ROSINA data has revealed a sort of chemical thread during the whole process of star formation, in which phosphorus monoxide plays the dominant role," says Victor Rivilla.

www.almaobservatory.org

NEWS IN BRIEF

SpaceX's abort test

SpaceX successfully tested the abort system of its Crew Dragon capsule on 19 January. The procedure was trialled during the most intense part of the launch – known as MaxV – and SpaceX purposefully set fire to the launch rocket to ensure the system would protect passengers even in the most extreme scenario. The spacecraft is now cleared for a crewed test flight later this year.

Ancient stardust uncovered

The oldest piece of stardust ever found has been discovered inside a meteorite. Astronomers at Chicago's Field Museum estimate the dust is seven billion years old. It predates the Sun by 2.5 billion years and originated in the pre-solar nebula that created the Solar System.

Nova set for 2083

A star in the constellation of Sagitta is expected to go nova by the end of the century. V Sagittae is a binary system where a white dwarf is cannibalising material from a nearby star, causing it to brighten. Around 2083, the two will collide and explode, temporarily becoming the Milky Way's brightest star.

The hottest planet is tearing itself apart

Temperatures are so extreme that the world's atmosphere is fiercer than some stars

The hottest planet ever discovered is so overheated that it is tearing apart its own atmosphere, according to a recent study using the Spitzer Space Telescope.

The planet, KELT-9b, is an ultra-hot Jupiter, meaning it's a gas giant orbiting close to its star – it takes just one and half days to orbit. The proximity means the world is tidally locked, with one side always facing its star.

The planet was discovered in 2017 by the Kilodegree Extremely Little Telescope (KELT) and it was immediately apparent that the world's atmosphere must be extremely hot. A team of astronomers quickly sought time on NASA's Spitzer Space Telescope to create a map of the planet's temperature in infrared.

Spitzer observed KELT-9b at several points during its orbit, when different parts of the planet were facing Earth, allowing astronomers to build up a global picture of how heat is distributed across the planet. They discovered that dayside temperatures reach 4,300˚C, making it the warmest planet on record and hotter than some stars.

"This kind of planet is so extreme in temperature, it is a bit separate from a lot of other exoplanets," says Megan Mansfield from the University of Chicago, who led the study.

The map showed that the nightside was cooler than the dayside but not by much, meaning there are wind currents mixing the atmosphere between the two. The team also found the dayside temperatures are high enough to dissociate the hydrogen, where the bond between two atoms in a hydrogen molecule breaks. When the dissociated atoms flow around to the nightside, the temperatures are cool enough for them to recombine, only for the planetary wind to blow the newly rejoined molecules round to the dayside to be torn apart again.

"There are some other hot Jupiters and ultra-hot Jupiters that are not quite as hot but still warm enough that this effect should be taking place," says Mansfield.

Astronomers will continue to study the planet to understand how the effects of this dissociation and recombination balances out with the flow of heat around the planet in an effort to understand these most extreme worlds.
http://www.spitzer.caltech.edu

Taking the heat: dayside temperatures on expoplanet KELT-9b (below, right) are 4,300˚C

NASA/JPL-CALTECH X 3

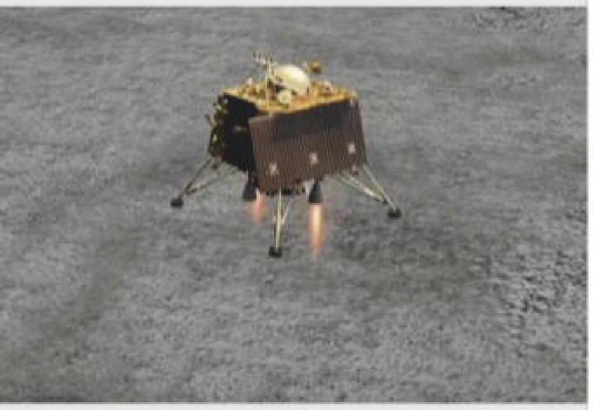
The Jack-o-Lantern Nebula, just one of the many stunning images brought to us by the Spitzer Space Telescope (inset)

Spitzer sees its final light

NASA shut down its Spitzer Space Telescope for the last time on 30 January. The infrared space telescope launched in 2003 and, for over 16 years, revealed a side of the cosmos hidden from our human eyes. It has pierced through clouds of dust which shroud or view within the Milky Way and looked out to study the most distant galaxies in the Universe.

"Spitzer taught us how important infrared light is to understanding our Universe, both in our cosmic neighbourhood and as far away as the most distant galaxies. The advances we make across many areas in astrophysics in the future will be because of Spitzer's extraordinary legacy," says Paul Hertz, director of astrophysics at NASA.

NEWS IN BRIEF



India to return to the Moon

The Indian Space Research Organisation (ISRO) confirmed it will be returning to the Moon with the mission Chandrayaan-3. The agency will make a second attempt to land on the lunar surface after its Vikram lander failed to touch down in September 2019. The new mission will fly no sooner than 2021.

First cookie in space

Astronauts Luca Parmitano and Christina Koch filled the ISS with the smell of freshly made cookies after baking the first biscuits in space. This 'Great ISS Bake Off' was part of an experiment into how food cooks in space. The crew didn't taste them, instead returning them to Earth for tests to see if they are fit for human consumption.

Galaxy crash

A collision between the Milky Way and a dwarf galaxy, Gaia-Enceladus, has been dated to 11.5 billion years ago. The galactic crash is one of many in our Galaxy's 13.5 billion-year history, and astronomers managed to place a date by using ground and space-based scopes to determine the age of the stars left behind.

ISRO, NASA AND L. HUSTAK (STSCI), NASA/JPL-CALTECH

'Vampire' star preys on stellar companion

The pair briefly flared up 1,000 times brighter than normal

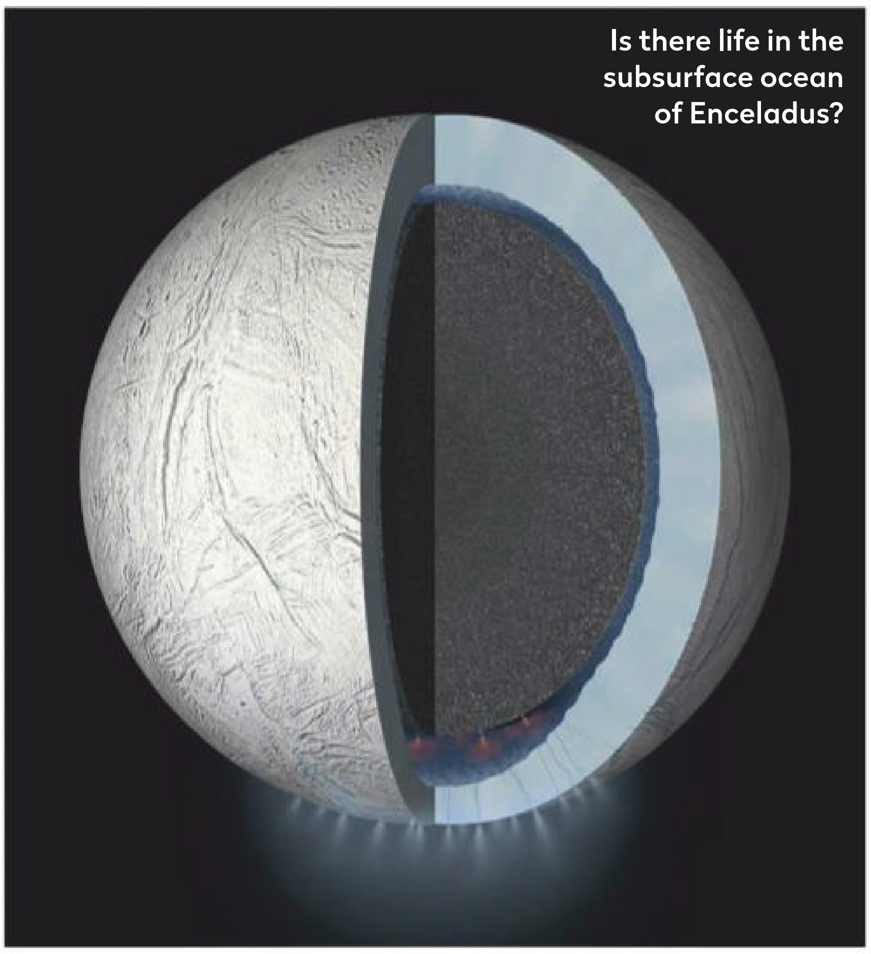
Energy drain: a dwarf star sucks the life from its companion

A 'vampire' star has been caught in the act of feeding off its stellar companion. The gluttonous star was uncovered by a new computer program which looks through archived data from NASA's Kepler Space Telescope, hunting for rapidly changing astronomical events. The program highlighted what turned out to be a white dwarf in the act of devouring its companion brown dwarf – a failed star which straddles the line between star and planet.

"The incredible data from Kepler reveals a 30-day period during which the dwarf nova rapidly became 1,600 times brighter before dimming quickly and gradually returning to its normal brightness," says Ryan Ridden-Harper from the Australian National University, who led the research. "The spike in brightness was caused by material stripped from the brown dwarf that's being coiled around the white dwarf in a disc."

www.nasa.gov

The complex core of ice moon Enceladus



Is there life in the subsurface ocean of Enceladus?

Saturn's moon, Enceladus, could have a geologically complex core, making it more likely to be hospitable to life. A new study measured the levels of carbon dioxide in the moon's subsurface ocean, which suggest it has interacted with the ocean floor. Astronomers used observations from NASA's Cassini orbiter, which observed jets of ocean water erupting through the surface back in 2015.

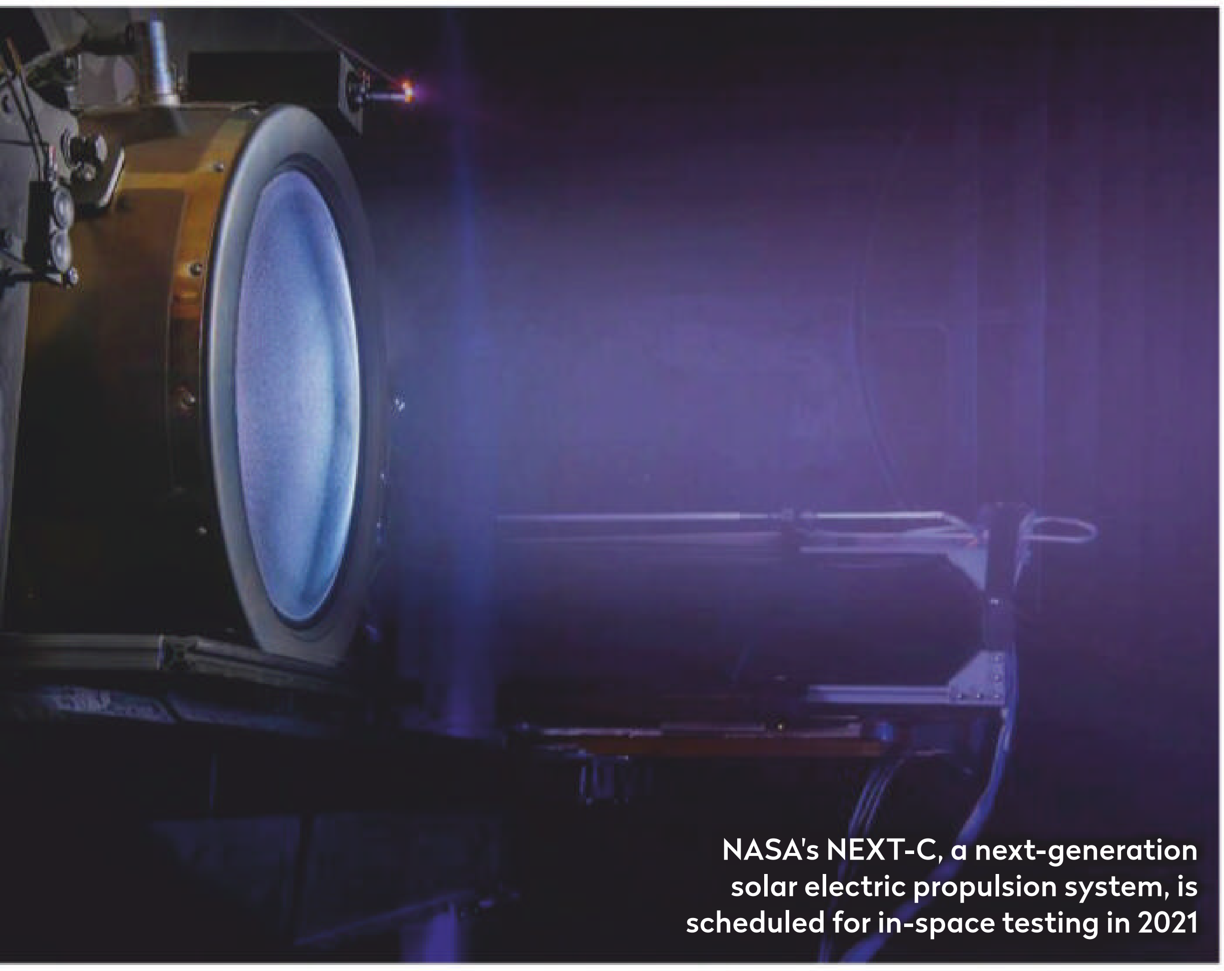
"By understanding the composition of the plume, we can learn about what the ocean is like, how it got to be this way and whether it provides environments where life as we know it could survive," says Christopher Glein from the Southwest Research Institute, who led the research.

The observations suggest that there could be complex geological features, such as hydrothermal vents, which affect the water.

"The dynamic interface of a complex core and seawater could potentially create energy sources that might support life," said Hunter Waite, principal investigator of Cassini's Ion and Neutral Mass Spectrometer.

http://solarsystem.nasa.gov

CUTTING EDGE



NASA's NEXT-C, a next-generation solar electric propulsion system, is scheduled for in-space testing in 2021

Taking the slow lane to Saturn

A new route could help spacecraft reach the outer Solar System

Designing a space mission is a balancing act, there are lots of different constraints to find an optimum solution for a spacecraft's trajectory. To keep interplanetary journey times short, you initially want to propel a spacecraft away from Earth as fast as possible. But whatever the launch vehicle, the faster this initial throw the smaller and lighter the space probe has to be, which limits the amount of scientific instruments and fuel it can carry. And in order for your mission to be captured into orbit around Saturn, for example, you have the problem of how to slow the probe down again when it arrives, because the outer planets circle the Sun far slower than Earth does. ESA's Cassini–Huygens probe used a big rocket burn to brake into Saturn's orbit, but manoeuvres like this require a huge amount of fuel, which then makes your probe very heavy to launch.

Traditionally, spaceflight has relied on chemical rockets. These can deliver an enormous thrust but require a huge mass of fuel and can only be used in short bursts. More missions are now using electric propulsion systems. These produce only a gentle push but are extremely fuel efficient and can be operated for months at a time. For example, NASA's Dawn, JAXA's Hayabusa and ESA-JAXA's BepiColombo missions have all exploited this technology.

Keeping a low launch mass

Elena Fantino, at Khalifa University of Science and Technology, Abu Dhabi, and her team have been investigating how such electric thrusters can be used to optimise the interplanetary route used for sending probes to Saturn, or beyond. How do you keep the launch mass as low as possible, while keeping a relatively quick journey time, and not arriving at Saturn too fast?

Fantino based her studies on the propulsion capabilities of the NASA Evolutionary Xenon Thruster – Commercial (NEXT-C), and a route to Saturn that uses a Jupiter fly-by for gravity assistance. The best solution she found is for the electric propulsion to accelerate the space probe from Earth to Jupiter as quickly as possible, but then once past Jupiter the probe constantly re-orientates to use its thruster to brake and match the planet's velocity. The probe is then moving slowly enough relative to Saturn that it can finally be captured into orbit using a single fly-by of Titan, or perhaps even by deploying novel technologies like an 'electrodynamic tether' which effectively digs its heels in against a planet's magnetic field.

"Electric propulsion systems produce only a gentle push but are extremely fuel efficient and can be operated for months at a time"

The Cassini-Huygens launch mass was 5.6 tonnes – much of which was rocket fuel – and it got to Saturn after fly-bys of Venus (twice), Earth and then Jupiter. Using Fantino's new trajectory optimised for electric propulsion en route, transit time is longer, but she calculates that future probes could be as small as just one tonne and far cheaper. And this opens up the possibility of launching a whole cluster of probes to explore an outer planet like Saturn at the same time.

Prof Lewis Dartnell is an astrobiologist at the University of Westminster

Lewis Dartnell was reading... *Reduction of Saturn Orbit Insertion Impulse using Deep-Space Low Thrust* by Elena Fantino et al. **Read it online at: https://arxiv.org/abs/2001.04357**

Solving gravity's oldest problem

The 'three-body problem' has long been the bane of astrophysicists

Prof Chris Lintott is an astrophysicist and co-presenter of *The Sky at Night*

Sometimes, even simple things can be complicated. Physicists have known this for centuries, driven mad by the complexities that lie in even simple problems of celestial mechanics.

Isaac Newton knew that if you have a system involving two objects – a single planet orbiting a star, for example – then with a little understanding of how gravity works you can calculate how both will move. Add a third object to the system, like a moon, and that predictability disappears. Things start off alright, but even a tiny change in the starting positions of any one of the three objects soon produces wildly different predictions for what the state of things will be in the future. As we can never know the initial positions of the three objects to infinite precision, then this chaotic behaviour means that the state of the system in the far future (and the distant past) is hidden from us and cannot be calculated.

Not as simple as it seems

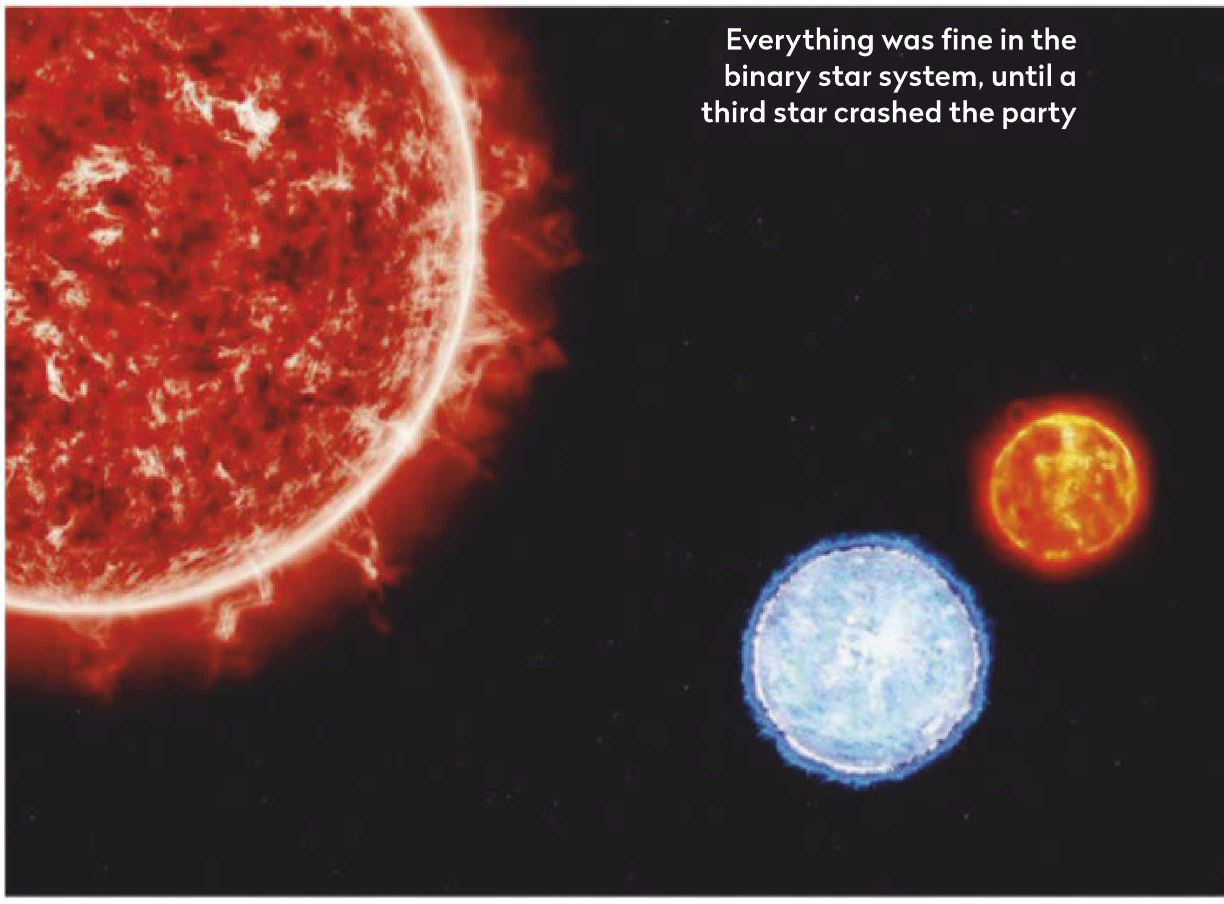
This 'three body problem', as it's come to be known, is a big headache. In physics textbooks and university exam papers, you can have a perfectly isolated system consisting of just a star and an orbiting world, but the real Universe shuns such simplicity. In star forming regions, in clusters of stars and galaxies, in planet formation and in the interaction of black holes, the dance objects undertake involves triple systems more often than not.

Luckily, although the three-body problem can't be solved analytically (where a set of equations leads to a single, definitive answer), some progress can be made. A new paper from two astronomers sheds new light on this old problem, taking a statistical approach to what might happen. The systems they studied are created when a nice, predictable binary star is approached by a third star, the kind of thing that must happen all the time in young clusters of stars. For most of the time, the models show that the resulting triple system will behave as a binary with a distant, third star interacting only weakly with the two at the centre, but as that interloper swings around there come periods of time where a mad scramble ensues.

"This period ends when one of the stars is thrown back out to a distance where it is just a third star, a process which repeats and repeats"

This period ends when one of the stars is thrown back out to a distance where it is just a third star, a process which repeats and repeats until a star is ejected completely. These calculations aren't analytical predictions of what might happen – they're just what the computer program thinks will happen next in any given circumstance. The clever bit is that by running many such simulations the team could get a prediction of what is likely to happen.

That will be of enormous help to astronomers working in all sorts of fields, but one group looking extremely closely will be those trying to understand the collisions of black holes that produce the gravitational waves observed by facilities such as LIGO (the Laser Interferometer Gravitational-Wave Observatory). Trying to understand how and why such black holes might form and collide has been difficult, but if interactions with a third object can encourage black holes to eventually merge, then the solution might lie in these clever statistical solutions to one of the oldest problems in the books.



Everything was fine in the binary star system, until a third star crashed the party

Chris Lintott was reading… *The NANOGrav 11-year Data Set: Constraints on Planetary Masses Around 45 Millisecond Pulsars* by EA Behrens et al. **Read it online at: https://arxiv.org/abs/1912.00482**

The Sky at Night TV show, past, present and future

INSIDE THE SKY AT NIGHT

▲ **Back to school: Maggie Aderin-Pocock goes back for telescope-making lessons with Terry Pearce**

January's *Sky at Night* episode saw Maggie Aderin-Pocock return to her old telescope-making class, run by **Terry Pearce**. He tells us about it

Having Maggie Aderin-Pocock, a co-presenter of *The Sky at Night*, come back to our club during the filming of a recent episode was a very satisfying experience for me and my colleague Simon Lang.

We first met Maggie over 30 years ago, when she attended the Camden Amateur Telescope Society's telescope-making sessions, which we still run at the Highgate Newtown Community Centre in London.

I took over the club from my good friend Doug Daniels when it was still an astronomy class and after several years of being asked where students could buy a good instrument I decided to start running telescope-making classes.

During the early years, making a telescope was much cheaper than buying one. It was possible to make a 6-inch reflector for £60 to £80, whereas to buy the equivalent size was several hundred pounds. Students would hopefully complete their mirrors in a year and then spend the next year downstairs in the metalwork class making the mounting and tube assembly. With the relatively inexpensive equipment available today, members are now more motivated by the satisfaction of being able to make their own optics.

Several decades ago, we agreed to take on a school-aged student in the class: this was Maggie. Both Simon Lang and another class member, Paul Clements, helped her create a 6-inch set of Cassegrain mirrors but she didn't require much aid – she was one of our more competent students. I gather that she continued her project when she studied at University College London.

I had an idea what to expect when Maggie came to see us with *The Sky at Night*, as I had recently helped the Science Museum with its exhibition: 'Science City 1550–1800'. This uses films of present-day craftspeople engaged in work that is unchanged from the past.

Terry Pearce has led the Camden Amateur Telescope Society for 38 years

My part of the project was to make a mirror of speculum metal – an alloy of copper and tin which polishes to a high shine. The filming took place over two afternoons, to cover the grinding and polishing, though I knew only a few minutes of film would actually feature.

Unfortunately, *The Sky at Night* TV crew didn't have enough time to show either myself or our many members at work crafting a mirror, but they were very polite and let me ramble on. They decided to call a rapid halt after I invited Maggie back to try our 'hot hand experiment'. To mirror makers this is an interesting diversion but it must sound like a bizarre request to anyone in the wider world. In truth, the 'hot hand experiment' is a test where someone places a hand into a beam of light while testing their mirror. The calm view is instantly distorted with turbulent air. It is a timely reminder that no matter how perfectly a mirror is figured, the moving, boiling air between ourselves and the stars finally governs our views of the night sky.

I'm glad we got to showcase our classes on *The Sky at Night*. It's amazing to think that making an astronomical mirror is one of the most precise tasks one can undertake, and we do so using techniques that are hundreds of years old.

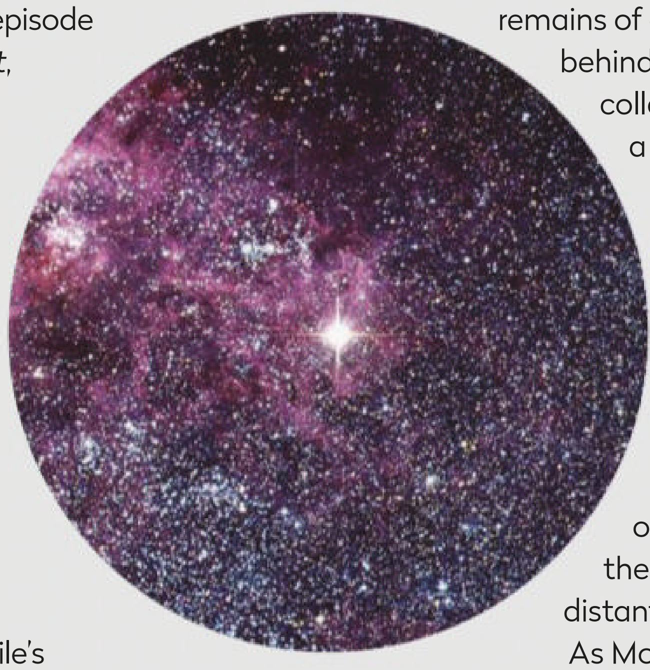
Looking back: The Sky at Night

12 March 1989

In the March 1989 episode of *The Sky at Night*, Patrick Moore and astronomer Paul Murdin looked towards the remains of SN 1987A. The supernova explosion was first spotted on 23 February 1987 in the Large Magellanic Cloud. Two years later, astronomers at Chile's Cerro Tololo Observatory noticed that the brightness of the expanding cloud of debris left behind was rapidly fluctuating over a night. The excited observers began to wonder if they were seeing the signs of a new pulsar peeking out from the thick dust.

A pulsar is a rapidly rotating neutron star, which are themselves the dense remains of a stellar core left behind after it has collapsed and caused a supernova. Pulsars emit a beam of intense radiation, which sweeps across the sky as it spins. From Earth, we see this as a regular pulse of light, like the flashing of a distant lighthouse.

As Moore and Murdin discussed the new find, the world's telescopes were turning towards SN 1987A and hunting for signs of the infant pulsar, but they struggled to make any direct measurements through the dense cloud. Even today, telescopes can only look at the surrounding gas, searching it for signs of the infant pulsar growing within.



▲ **Scientists are still hunting for signs of a pulsar in SN 1987A**

The Sky at Night returns in April

The Sky at Night is taking a break this month and will return in April. In the meantime, there is a wealth of space, astronomy and other science programming available on the BBC iPlayer (**bbc.co.uk/iplayer**), including *8 Days: To the Moon and Back*, which chronicles the Apollo 11 mission; *The Extra-Terrestrial Funeral Service*, which features a UK company that scatters ashes in space; and Brian Cox's latest series *The Planets*, exploring the Solar System's history. Plus, visit **bbc.co.uk/sounds** for a range of science podcasts, including an episode of *In Our Time* in which Melvyn Bragg and guests discuss Ptolemy and the history of ancient astronomy.

▲ **Catch Brian Cox's latest astronomy series while it's still available on the iPlayer**

Emails – Letters – Tweets – Facebook – Kit questions

INTERACTIVE

Email us at **inbox@skyatnightmagazine.com**

MESSAGE OF THE MONTH

This month's top prize: four Philip's books

PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2020 Stargazing*.

Winner's details will be passed on to Octopus Publishing to fulfil the prize

Praises on high

With all the news about Betelgeuse – I penned this:

An Astronomer's Prayer

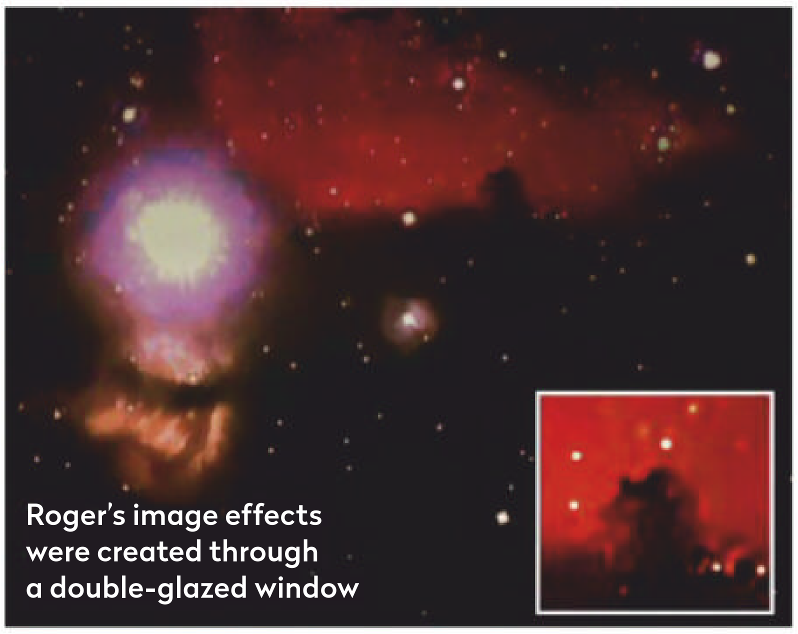
Dear Lord may you bless our equipment today,
And please we beseech, blow the clouds all away,
The stars in the sky, the planets above,
The folks who look up and the hobby we love.
Make each shining star glow bright in the sky,
And show us the galaxies, a treat to the eye,
Each evening please give us some heavenly hope,
That come 8 o'clock, we can set up our scope,
We love when you show us meteors flying over,
But please in our lifetime, make Betelgeuse go Nova.
Amen!

David Millar, via email

Amen indeed, David! A delightful verse; it captures the mood perfectly. **– *Ed.***

Tweets

Sophie Cooper
@sophiecooper193 • Jan 19
Look up! That bright beauty lighting the #nightsky is #Venus! Hooray for clear skies! View from #Somerset garden! #stargazing #astronomy #space @GoStargazing @BBCStargazing @skyatnightmag #nature #365dayswild



Roger's image effects were created through a double-glazed window

Sill photography

These images of the Flame and Horsehead Nebulae may be of some interest, not because of the images of these popular targets themselves (by normal standards, they are rather poor) but because of how they were acquired. They were taken using my 80mm f/5 refractor with a focal reducer, on a table-top EQ1 mount sitting on a bedroom windowsill, looking through a double-glazed window. The camera was a Phil Dyer integrating video camera, and the image is from a stack of 39 x 10-second exposures, giving a total exposure of 6.5 minutes. It was then processed using GIMP 2.10. It would seem that this technique breaks all the generally accepted rules for imaging and observing, but rules are there to be broken. You don't need expensive or elaborate kit to get quite satisfying images. The total cost of all the equipment (apart from the PC) was only a few hundred pounds, and the software involved was free (SharpCap, RegiStax and GIMP).

Roger Samworth, Nuneaton

Orion in a new light: Tom's inventive low-polygon illustration

Creative flair

I've been reading the magazine since October last year, and I've enjoyed so much about it. I was hoping to share a bit of work I've done, combining astrophotography and digital design. I only got into astrophotography last September with the purchase of a Celestron NexStar 127 SLT for my birthday, and a donated Canon Rebel T5i (also known as the 700D here in the UK). I had imaged the Orion Nebula back on 16 November and was pretty happy with the resulting composite image (left). Being a graphic designer of a few decades, I took the photo one step further and created a meticulous low-polygon illustration of the Orion Nebula (above). There are over 1,000 individual elements, including the stars that were visible in the photograph, that make up the resulting image. I hope you like it.

Tom Harbin, via email

Galaxy view

I was fortunate enough to be able to see the Milky Way recently from my local dark sky site at Beachy Head. As I was observing it a question crossed my mind which has continued to confuse me: that is, can a ▸

ON FACEBOOK

WE ASKED: What are your top tips for observing or photographing the Moon?

Mick Cassidy The phases before and after a new Moon are best, a very bright Moon can make it difficult to image.

Julie Straayer Observe before it gets too full, either before or after full Moon, to get more contrast from shadows formed by the Sun's low angle. I mostly use my smartphone when imaging the Moon. I like to use my Maksutovs, which give lovely contrasting views that are very sharp.

Abi Mark Garvey Before I had a Moon filter I used the blue cellophane wrapper off a Quality Street sweet!

Matthew James Bailey Just grab some binoculars! Most households have a pair somewhere.

Michael Bate Observe through a neutral density filter and focus on the terminator for stunning views. Check the phase in advance so you know what'll be on show to plan your targets.

Diana Lynn Keep images interesting. I use trees in the foreground.

SCOPE DOCTOR

Our equipment specialist cures your optical ailments and technical maladies

With **Steve Richards**

Email your queries to scopedoctor@skyatnightmagazine.com

I've just bought a Sky-Watcher SkyMax 127 AZ-GTI and want to photograph planets, comets, nebulae and the odd galaxy. What planetary cameras can you recommend for around £150?

TOM MARTIN

▲ The ZWO ASI 120MC-S USB 3.0 Colour Camera is a good companion

The Sky-Watcher SkyMax 127 AZ-GTI would make an excellent telescope for planetary and lunar observing and imaging. However, it would be less suitable for imaging deep-sky objects as it has an altazimuth mount rather than an equatorial one.

For planetary imaging you have the choice of a one-shot colour camera or a mono camera plus a set of colour filters. The latter can capture all the colours in a single shot, which means you don't get any problems caused by the planetary subject rotating on its axis in between images taken with different filters. You can also keep below your budget by not buying filters.

The ZWO ASI 120MC-S USB 3.0 colour camera just fits into your budget. Planetary and deep-sky imaging are pretty much mutually exclusive but the included 150° lens would allow you to capture some fascinating wide-field Milky Way and constellation images. It's £20 over your budget but the Altair GPCAM2 IMX224 colour camera is another option.

Steve's top tip

How do I set up my finderscope?

A finderscope is a simple but invaluable accessory that attaches to your telescope. The smaller optical tube provides a wide field of view to help you locate celestial objects before observing them through your main telescope, but importantly, it must be aligned accurately to your scope before it can be used.

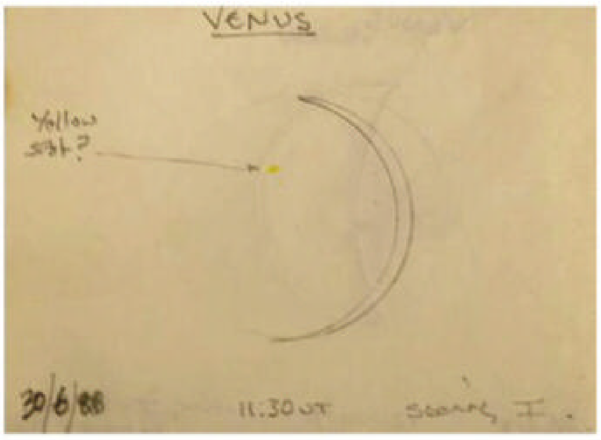
Start aligning in the daytime by finding a very distant object using your telescope, centring that object in your eyepiece as accurately as you can. Then, without moving the telescope, observe through the finderscope and centre its crosshair on the same object by adjusting the three alignment bolts that hold the finderscope in its cradle.

Steve Richards is a keen astro imager and an astronomy equipment expert

CELESTRON, KIRISA99/ISTOCK/GETTY IMAGES

▸ casual observer tell which direction we are looking into our Galaxy from Earth? And related to that, how do we know scientifically? Are we looking at our local arm or across the whole plane? Which direction is the centre and how do we know?
Antony Hatton, via email

We look through different parts of the Milky Way throughout the year, with the centre visible from March to October. We know because astronomers have spent years tracking stars to create a 3D-map of our Galaxy. Currently, the Gaia spacecraft is monitoring over a billion stars to make this map even more accurate. ***– Ed.***



Venus solution

I read with interest in the December edition about Venus, its mysteries and its fabled Himalayan peaks, and wanted to thank Phil Miles and Anthony Wesley for their observations of the planet's night side and possible volcanic activity. I feel I now have the answer to a mystery from my own observations, made over 30 years ago (left), when I too observed a bright spot and a limb feature: volcanic activity!
David Greenwood, via email

Tweets

Lifepic
@Lifepic2 • Jan 29
@skyatnightmag early evening shot of the Moon & Venus. Leica D Lux 109, ISO 3200, 34mm, f2/8, 1/15 sec.

Correction

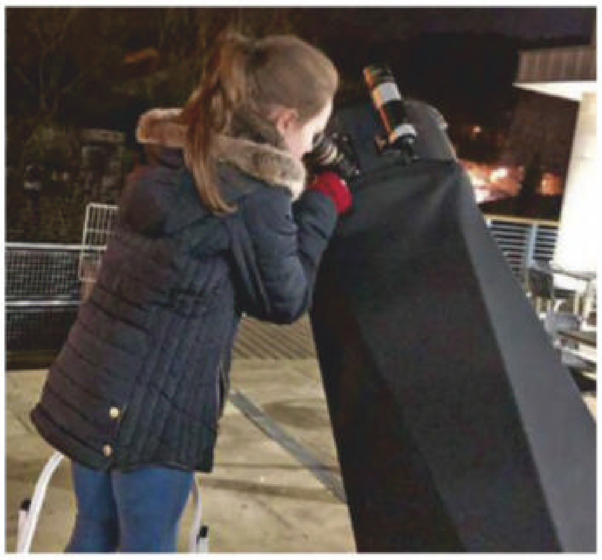
The February issue's *Field of View* column referred to its author Peter Williamson as an amateur astronomer, when his correct title is professional astronomer.

SOCIETY IN FOCUS

Yorkshire Astronomy is an organisation based in the beautiful Calder Valley, with the aim of making practical astronomy more accessible to the communities of Yorkshire and beyond, through family friendly community events, astro-glamping and astronomy and astrophotography workshops.

Astronomy in the Valley is a regular event we host at Hebden Bridge Town Hall for communities in the Calder Valley and we welcome families, seasoned astronomers and first timers. We also run astronomy and astrophotography workshops. These evenings begin with an introduction to DSLRs, their functions and the different lenses needed for dark-sky photography. Our participants then take a night walk on the Yorkshire Moors under our dark skies, using what they've learnt to capture features such as the Milky Way, the Orion Nebula and the Andromeda Galaxy.

In late February 2020, Yorkshire Astronomy is teaming up with Go Stargazing and the highest pub in the UK, the Tan Hill Inn, to take part in the North York Moors National Park Dark Skies Festival. Together we aim to create a series of events that will help make the wonders of the night sky and astronomy more accessible. Keep an eye on our website and the Tan Hill Inn's for more information and to book your place.



Jon Turner, founder, Yorkshire Astronomy
▸ **www.yorkshireastronomy.com**

BBC Sky at Night MAGAZINE
IMMEDIATE MEDIA Co

BBC Sky at Night Magazine is published by Immediate Media Company Bristol Limited under licence from BBC Studios, which helps fund new BBC programmes.

EDITORIAL
Editor Chris Bramley
Art Editor Steve Marsh
Production Editor Neil McKim
News Editor Elizabeth Pearson
Staff Writer Iain Todd
Reviews Editor Paul Money

CONTRIBUTORS
Nisha Beerjeraz-Hoyle, Shaoni Bhattacharya, Lewis Dartnell, Glenn Dawes, Will Gater, Alastair Gunn, Amber Hornsby, Michael Lachmann, Pete Lawrence, Chris Lintott, Mark Parrish, Katrin Raynor-Evans, Steve Richards, Steve Sayers, Steve Tonkin, Steve Wallace, Jane Williamson, Peter Williamson

ADVERTISING SALES
Advertising Manager Sam Jones +44 (0)117 300 8145, sam.jones@immediate.co.uk
Inserts Laurence Robertson +353 (0)87 690 2208

PRODUCTION
Production Director Sarah Powell
Production Coordinator Derrick Andrews
Ad Services Manager Paul Thornton
Ad Coordinator Florence Lott
Ad Designer Parvin Sepehr
Reprographics Tony Hunt, Chris Sutch

LICENSING
Director of Licensing and Syndication Tim Hudson
International Partners' Manager Anna Genevier

MARKETING
Head of Circulation Rob Brock
Head of Marketing Jacky Perales-Morris
Marketing Executive Craig Ramsay
Press and PR Manager Emma Cooney

PUBLISHING & MANAGEMENT
Publisher Jemima Dixon
Managing Director Andy Healy
Group Managing Director Andy Marshall
CEO Tom Bureau

BBC STUDIOS, UK PUBLISHING
Chair, Editorial Review Boards Nicholas Brett
Managing Director, Consumer Products and Licensing Stephen Davies
Head of Publishing Mandy Thwaites
Compliance Manager Cameron McEwan
UK Publishing Coordinator Eva Abramik
UK.Publishing@bbc.com; www.bbcstudios.com

SUBSCRIPTION RATES
Annual subscription rates (inc. P&P): UK cheque/credit card £62.40; Europe & Eire Airmail £75; rest of world airmail £85. To order, call 03330 162119 (UK); overseas +44 (0)1604 973727

We abide by IPSO's rules and regulations. To give feedback about our magazines, please visit immediate.co.uk, email **editorialcomplaints@immediate.co.uk** or write to The Editor, *BBC Sky at Night Magazine*, Immediate Media Co., Eagle House, Colston Avenue, Bristol, BS1 1EN.

Audit Bureau of Circulations
19,202 (combined; Jan–Dec 2018)

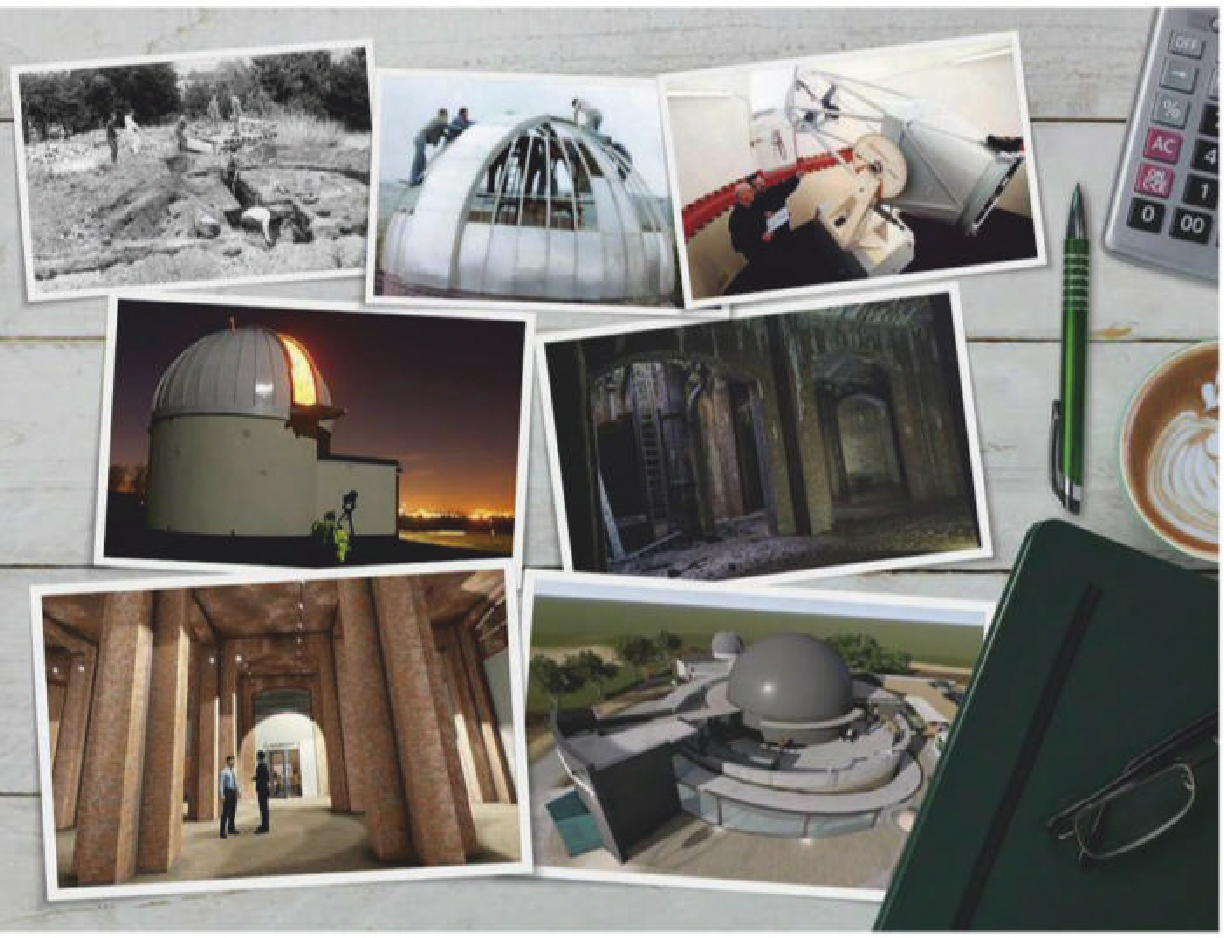
ISSN 1745-9869

The amateur astronomer's forum

FIELD OF VIEW

Turning a reservoir into a planetarium

One astronomy society has ambitious plans to build a science discovery centre and planetarium in a derelict reservoir next to their observatory



Dr Steve Wallace is the project manager of the Sherwood Observatory's Planetarium Project. To get in touch with him email **projectmanager@sherwood-observatory.org.uk**

Mansfield and Sutton Astronomical Society (MSAS) was established in 1970 when Dave Collins, a member to this day, placed an advert for like-minded people in the local newspaper. The founding members were ambitious and decided to build an observatory, and over the next decade the Sherwood Observatory was built on a shoestring budget. In an era when recycling did not have the profile that it has today, the demolition of a local coal mine provided many of the materials used to construct the building. The frame of our 61cm (24-inch) Newtonian refracting telescope was built from scaffolding poles and the equatorial axis from the rear axle of a truck. Even the main mirror was made by the members. MSAS is still a thriving society and we pride ourselves on our outreach projects, attracting nearly 3,000 visitors a year. We are a particular favourite with the Scouts and Girlguiding associations, and have helped over 50 groups attain their astronomy badge in the last year alone.

Today, the Society has ambitions every bit as big as those of its founders. In 2014 we bought the land adjacent to the observatory, the site of a redundant underground reservoir constructed in the 1880s. This 23m-diameter circular structure has a 5.5m-high, vaulted brick, arch roof supported by brick pillars and is an impressive example of Victorian industrial engineering.

After some consultation with society members and the public, we decided to set about turning the reservoir into a science discovery centre and planetarium and in 2018 we secured funding from the National Lottery Heritage Fund, the Architectural Heritage Fund and Ashfield District Council for a feasibility study. Surveys demonstrated that it was possible to repurpose the structure for its new use. Then during the summer just past, the University of Nottingham funded two architecture student interns to develop the designs.

The reservoir will contain a multi-purpose exhibition area and teaching space, designed to preserve the existing architectural heritage features. A 10m-diameter planetarium will sit on the roof of the reservoir and, as well as showing pre-prepared content, will have the capability to live stream the view from our observatory telescope. Making the site accessible to people with disabilities was a key part of the design brief and the students came up with an innovative proposal that uses ramps as the main access route, taking their design cue from the rings of Saturn. Our business plan shows that the new facility can be operated on a sustainable long-term basis, attracting around 20,000 visitors a year.

So far we've been fortunate enough to receive the support of several local companies and business groups for our venture. We will be applying for some significant blocks of funding during 2020 in order to progress our designs and to start the significant task of raising the capital required for the construction phase. If anyone is interesting in knowing more about the project or helping us in any way through donations or work in kind it would be great to hear from you!

NEIL PLEDGER, MSAS X 6, CHATTRAWUTT/ISTOCK/GETTY IMAGES

Our pick of the best events from around the UK

WHAT'S ON

Star Attractions 2020

National Museum, Cardiff, 21 March, 10am–4pm

A free day of astro activities, shows and displays for all the family, with loads of experts on hand, scopes of all types and sizes, meteorites to handle, an astronomy-themed stamp collection, 3D shows, planetarium and space talks. **bit.ly/Star-attractions**

Reservoir astronomy

Abberton Reservoir Visitor Centre, Colchester, 14 March, 6.30pm

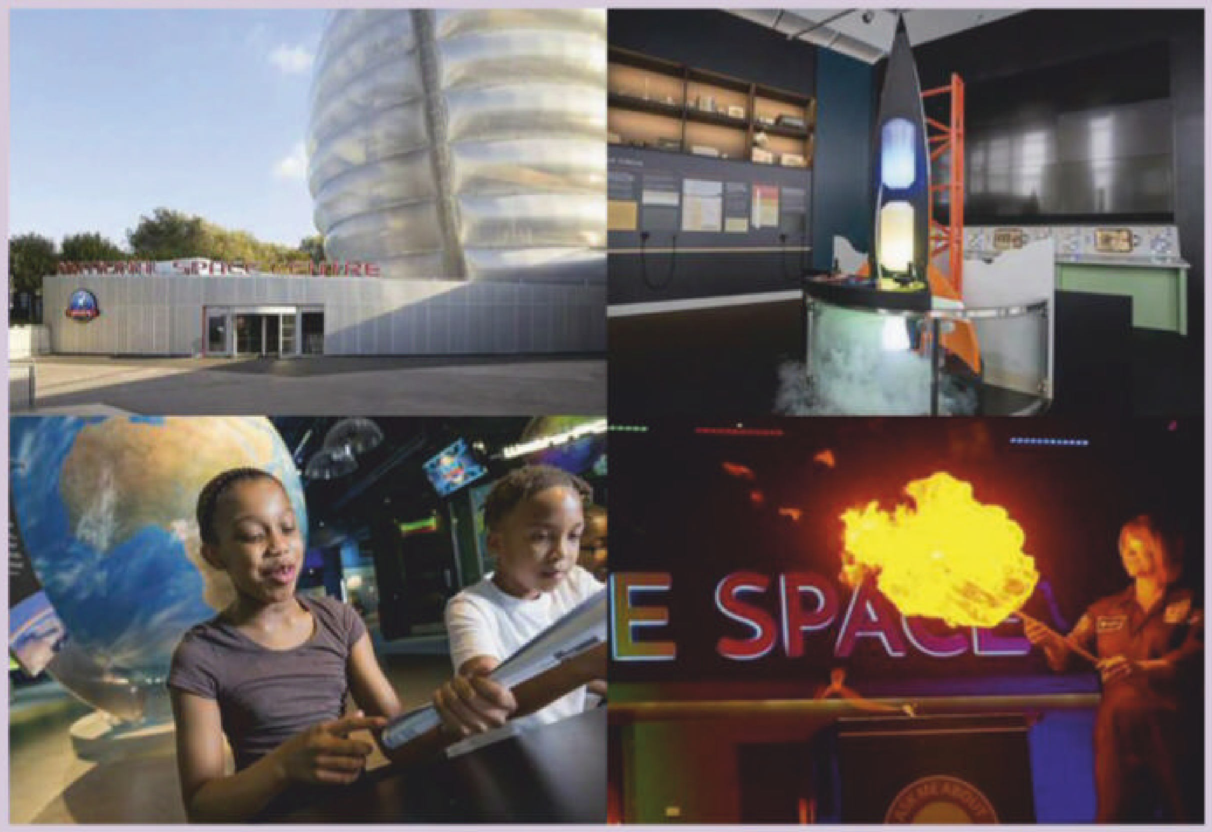
An evening of stargazing courtesy of Essex Wildlife Trust and North Essex Astronomical Society, with astronomy talks and large scopes provided. Bacon rolls too. Requested donation is £6 per adult, £4 per child. To book call **01206 738172**

Spring galaxy spotting

Richmond Memorial Hall, Tomintoul, 15 March, 8pm

With the Milky Way out of the way, now's the time to head to the Cairngorms Dark Sky Park to explore our galactic neighbours. A Whirlpool, a Cigar, a Sunflower and a Cat's Eye are the targets, with an indoor planetarium presentation if the weather misbehaves. **bit.ly/glenlivet-cairngorms**

PICK OF THE MONTH



▲ A day to remember: the whole family can enjoy the UK's plans for space exploration

UK in Space Festival

National Space Centre, Exploration Drive, Leicester, 7 March, from 10am

Some big names are heading to Leicester for this packed one-day festival celebrating the UK's contributions to space exploration.

Stellar headliners are astronauts Helen Sharman and Tim Peake, who will give a talk and Q&A about their experiences of living and working in space. Looking at the past and the future of human spaceflight is Anu Ojha, adviser on ESA's Human Spaceflight and Exploration programme, while – looking further out into our Solar System – Leigh Fletcher talks about coming missions, from Juno and JUICE to a planned voyage to Uranus and Neptune. Suzie Imber will be taking a closer look at enigmatic Mercury, while Gillian Wright will discuss the exciting new world of astronomy about to be opened up by the James Webb Space Telescope.

Another highlight is a talk by Paul Meacham, lead systems engineer on the Rosalind Franklin Mars rover being built by the British division of Airbus, plus special guest Bruno, a rover replica that Airbus experts will drive over a mini Martian surface. **spacecentre.co.uk/whats-on**

Kielder Forest Star Camp

Kielder, Northumberland, 18–22 March

What better place than this International Dark Sky Park for a five-day informal stargazing mixer? Bring your own kit and plenty of warm gear. Camp at Kielder campsite if you're hardy enough. Email **lynnhenderson@blueyonder.co.uk**

Practical Astronomy Show 2020

Kettering Conference Centre, 21 March

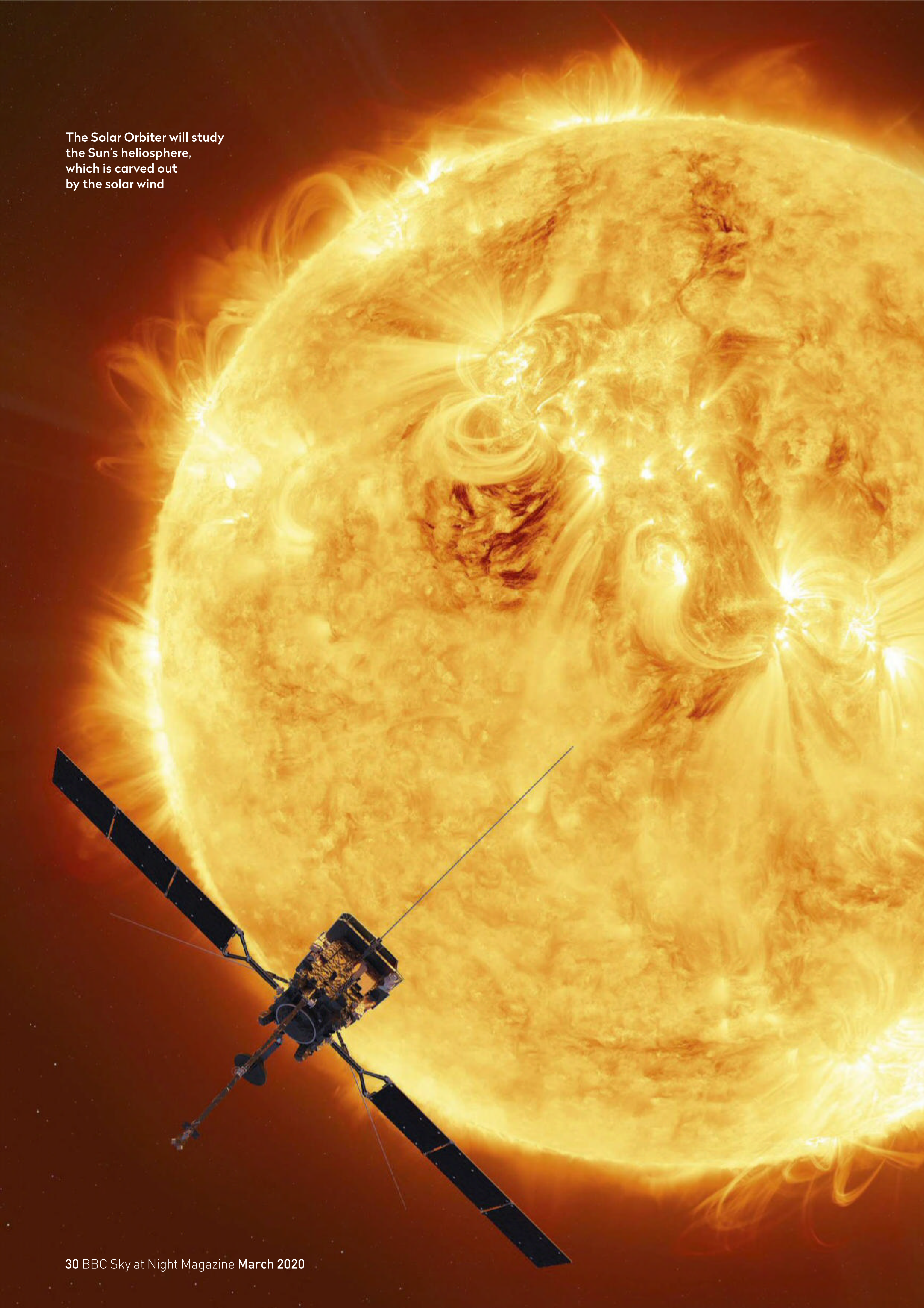
A free event with displays by all the big names in astronomy equipment, organisations and educational institutions. Look out for a talk by *BBC Sky at Night Magazine*'s Paul Money. **practicalastroshow.com**

Island stargazing

Isle of Coll, Inner Hebrides, 28–29 March

This stargazing weekend on the Hebridean island of Coll should be a memorable one. Telescopes are provided, along with a state-of-the-art cinematic planetarium. It's £90 for adults and £75 for 12–17 year olds. **bit.ly/islandstargazing**

NATIONAL MUSEUM/CARDIFF, NATIONAL SPACE CENTRE X 4



The Solar Orbiter will study the Sun's heliosphere, which is carved out by the solar wind

ESA/ATG MEDIALAB

Set the controls for the heart of THE SUN

ESA's Solar Orbiter launched earlier this month on a mission that will take it perilously close to the Sun. **Michael Lachmann** explores the science behind it

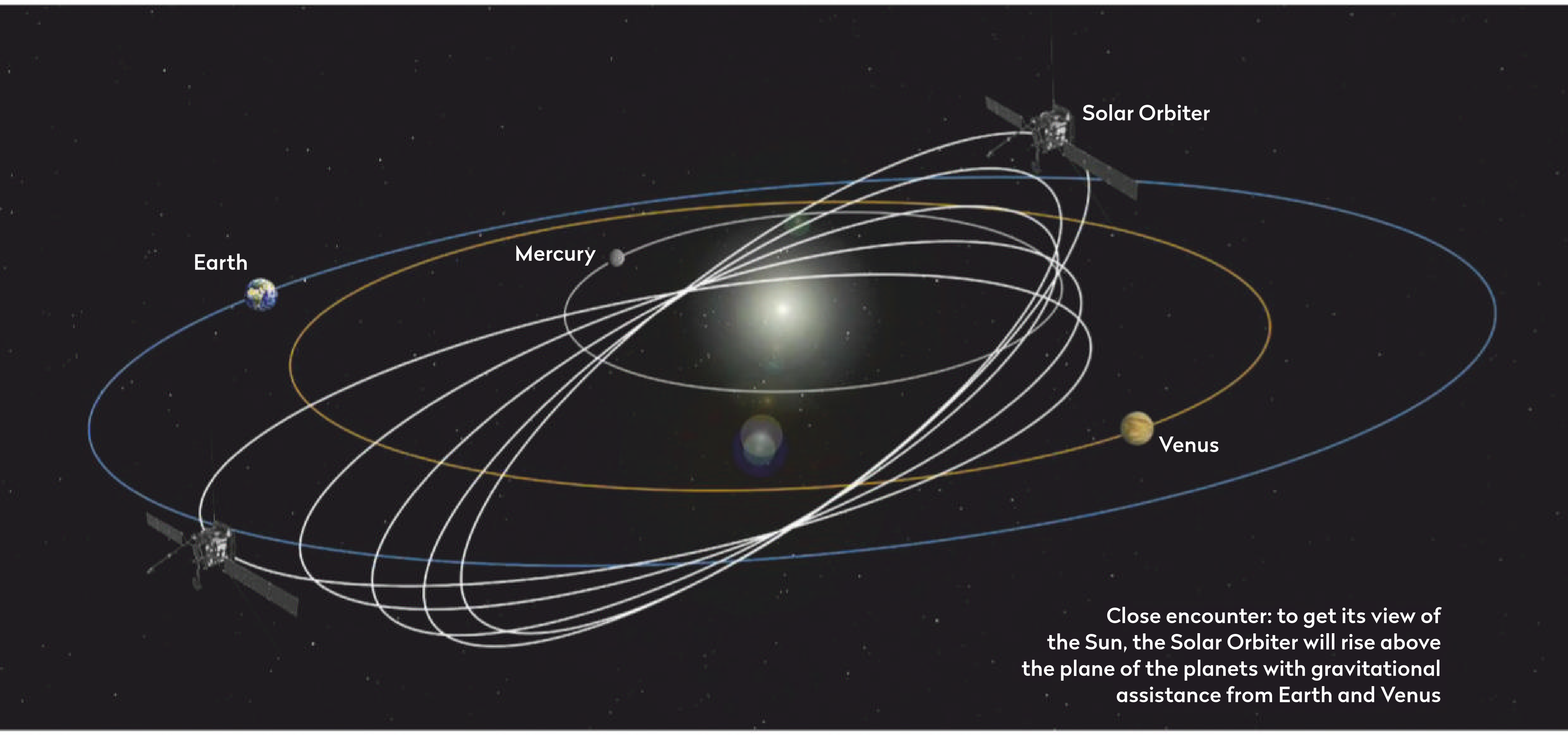
On 5 February, Just before midnight local time, an Atlas 5 rocket blasted off from Cape Kennedy in Florida carrying the European Space Agency's Solar Orbiter – one of the most ambitious spacecraft ever launched.

The aim of the mission is to study the heliosphere, the bubble in space carved out by the solar wind – the stream of charged particles that constantly flows away from the Sun. The heliosphere is vast. It envelops Earth and extends far beyond the orbit of Pluto.

It has far-reaching effects on all the Solar System's planets but, as Lucie Green, one of the scientists working on the mission, explains, studying it means flying into the Solar System's heart – into some of the most hostile environments ever encountered.

"What we want to do is get close to the Sun, so that we can measure material as it leaves the surface, before it's been processed and before it evolves," she says.

To get close enough to the Sun to collect that data the spacecraft will use three stages of gravity assistance, two around Venus and one around Earth, to enter a highly elliptical 180-day orbit that at its closest approach will pass just 42 million km from the solar surface. ▸



Close encounter: to get its view of the Sun, the Solar Orbiter will rise above the plane of the planets with gravitational assistance from Earth and Venus

▸ It will give us our closest ever views of the solar surface and will allow us to see parts of the Sun we have never seen before. As the mission develops the orbit will become more and more inclined, lifting the spacecraft higher and higher above the plane of the planets until it is able to look down onto the Sun's previously unseen polar regions.

Feeling the heat

In these regions close to the Sun, the spacecraft will be exposed to temperatures over 500°C. Designing a spacecraft that can endure these conditions for the length of the mission – which is planned at seven years but may extend to 10 – has been a huge challenge.

"It's a strange mission of extremes," says Alex Jacobs, the thermal architect at Airbus Space Systems, the prime contractor on the project. "One of the big challenges is that it is covering such a large distance. It's going incredibly close to the Sun, just inside the orbit of Mercury at its closest point, which is just 0.28 Astronomical Units (where 1 AU is the distance from the Earth to the Sun). But it also starts at Earth, which is a reasonable distance from the Sun. So you've got to design it to tolerate very intense heat when it gets close to the Sun, but also so that it doesn't get too cold when it's back up towards Earth.

The spacecraft's main defence against the Sun is its heat shield – which will almost always be pointed directly towards the Sun – leaving the rest of the spacecraft protected in its shadow.

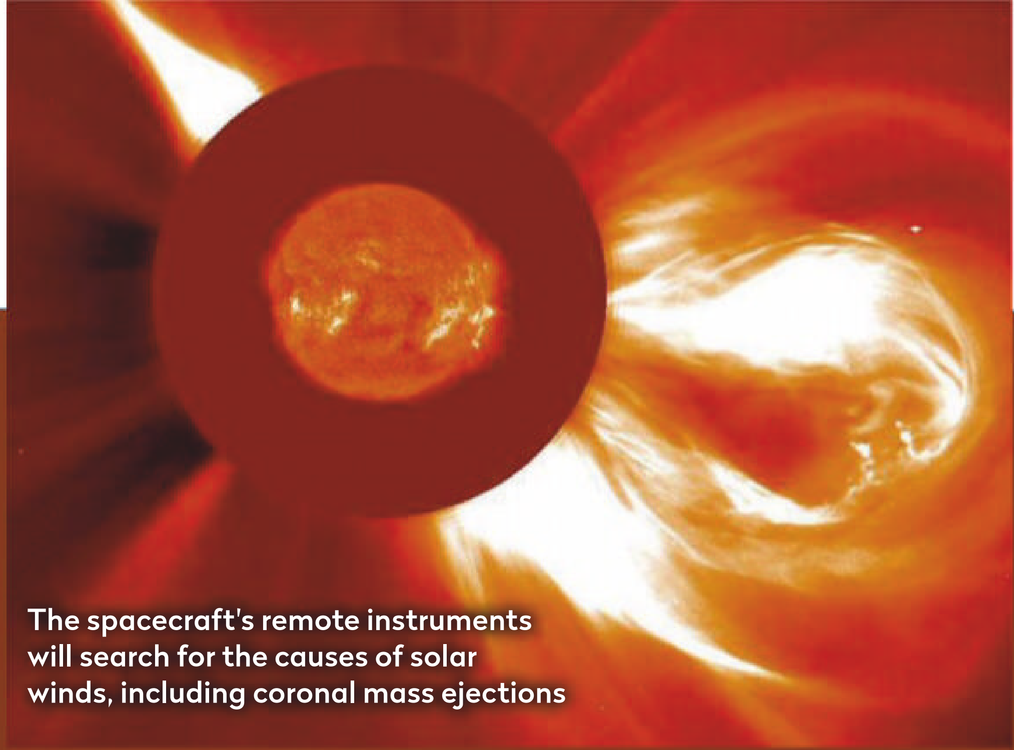
Connected to the body of Solar Orbiter by 10 tiny titanium strips to minimise heat transfer, the shield is made of a 5cm-thick layer of aluminium honeycomb designed to radiate heat into space. That is connected to a further layer of 20 wafer thin sheets of titanium that can withstand temperatures of 500°C.

But the most important element is the surface coating of the shield. The engineers knew that the surface of the heat shield had to be black – to allow it to soak up the Sun's heat and re-radiate it back into space. And crucially the material needed to be durable enough to survive for 10 years in space while maintaining its full performance – without fading or emitting any gas that would confuse the spacecraft's instruments.

To produce this coating ESA turned to the Irish medical device company Enbio – which created a solution called SolarBlack, combining cutting-edge manufacturing techniques with of one of the oldest technologies developed by humans.

▼ Having a blast: the Solar Orbiter's Sun shield was exposed to a beam of simulated sunlight produced by 19 xenon lamps – each consuming 25kW

ESA-ANNEKE LE FLOC'H, SOHO (ESA & NASA), COMPAGNON BRUNO/ALAMY STOCK PHOTO, ENBIO/NOVAUCD



The spacecraft's remote instruments will search for the causes of solar winds, including coronal mass ejections

Science at the Sun

The Solar Orbiter mission has been designed to answer four key questions about the solar wind. What are they?

1. How is the solar wind accelerated by the corona's magnetic field?

By studying the correlation between the solar wind and the changing properties of the magnetic fields in the Sun's corona, the mission hopes to reveal the mechanism by which particles in the solar wind are accelerated to speeds of up to 800km/s.

2. How do transient features on the Sun drive variability?

Sudden events on the Sun's surface, such as solar flares and coronal mass ejections, can have a huge impact on the intensity of the solar wind and can dramatically affect space weather on Earth. By observing these events at close range, the Solar Orbiter will help us understand the origin of these events with the ultimate aim of being able to predict them.

3. How do solar eruptions fill the heliosphere with energetic particles?

The Sun is the most powerful particle accelerator in the Universe. As well as the constant flow of the solar wind it also regularly emits storms of particles that travel at close to the speed of light. These high-energy particles can be detected at Earth's surface and can affect radio transmissions and air travel, but we don't know exactly where they come from on the Sun. The Solar Orbiter will attempt to identify the source of these particles.

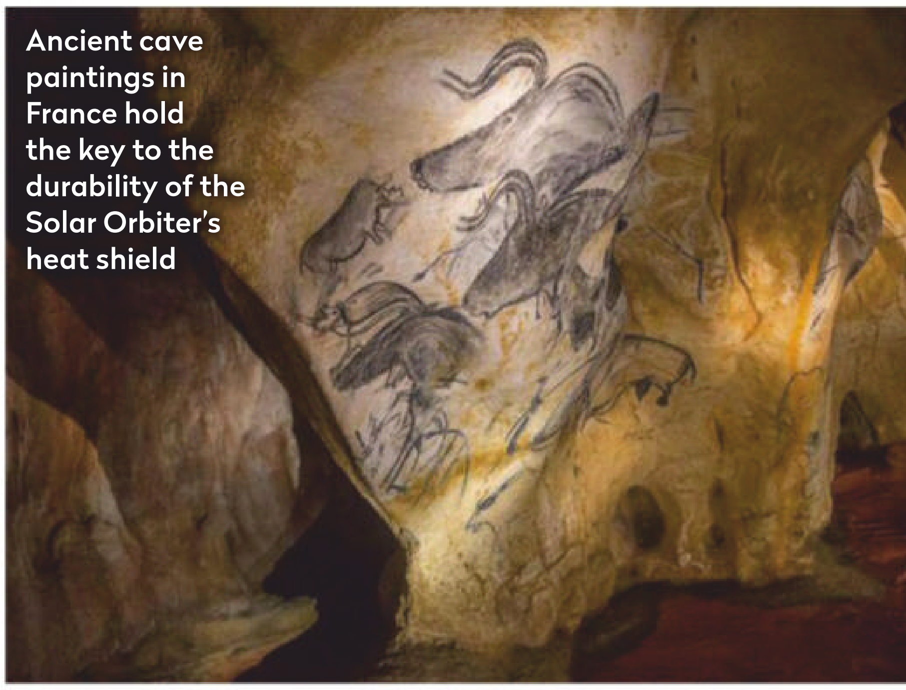
4. How does the solar dynamo work?

All the solar activity we see is ultimately generated by the Sun's magnetic field. We know the magnetic field varies over an 11-year cycle, but we don't know how the magnetic field is generated by the 'solar dynamo'. Solar Orbiter should help solve this mystery by providing the first detailed observation of the magnetic fields in the Sun's polar regions.

As Enbio founder and CEO John O'Donoghue explains, the technique was developed as a method for coating surgical implants: "This is technology that was designed for inner space – inside the body – but is now being used in outer space."

True grit

The technique used by Enbio involves using grit blasting to remove the surface oxide layer from the metal and replaces it with a new coating material that bonds permanently to the titanium underneath, creating a stable and very durable surface.



Ancient cave paintings in France hold the key to the durability of the Solar Orbiter's heat shield

Scientists remove the oxide layer of the heat shield

"The big advantage is that the new layer ends up bonded, rather than only painted or stuck on. It effectively becomes part of the metal," explains O'Donoghue.

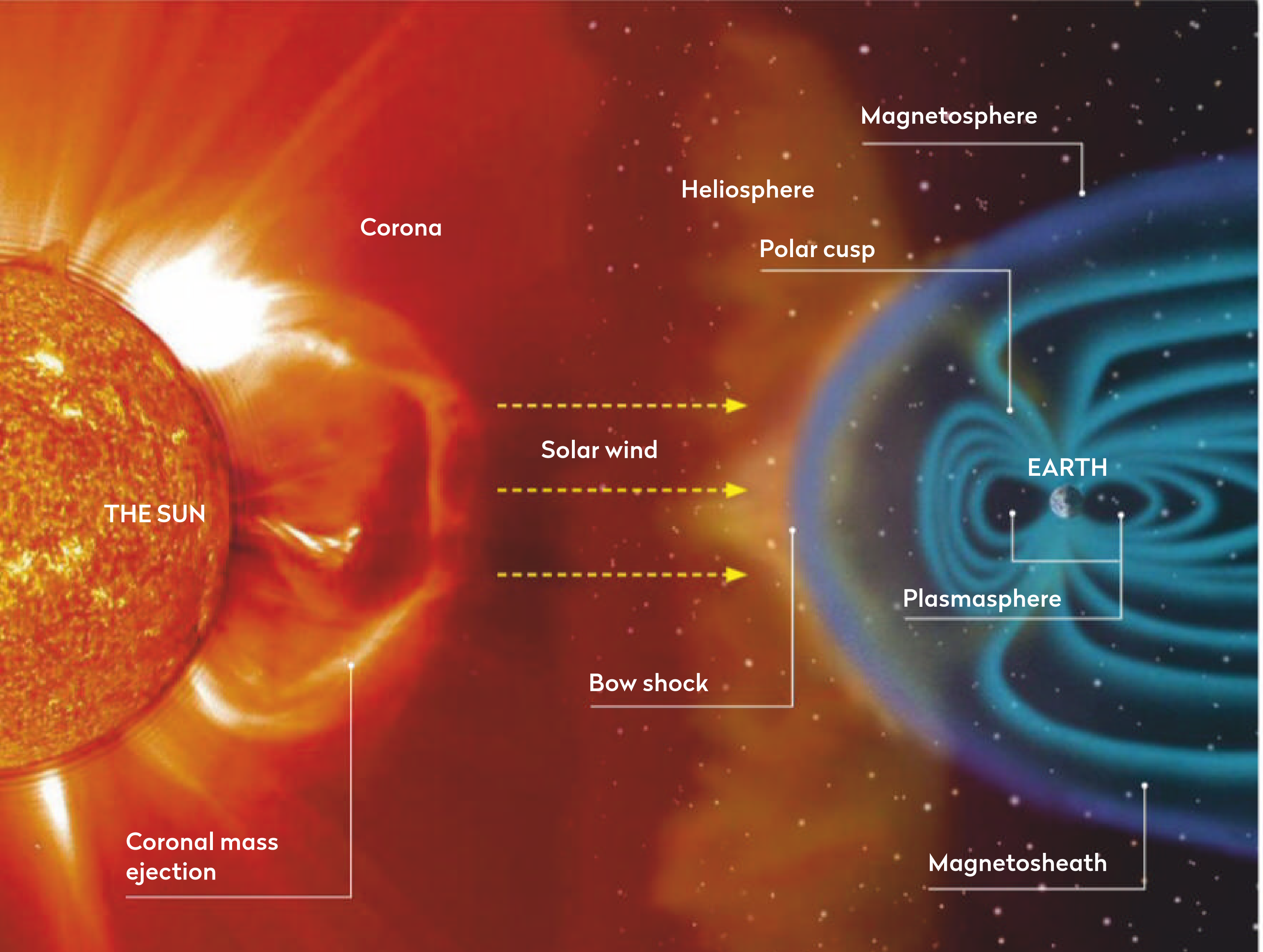
Surprisingly, the best coating material that Enbio found included a substance that people have been using since prehistoric times – burnt bone. Around 30,000 years ago stone age artists used charred animal bones to paint dramatic hunting scenes and animal portraits on the walls of caves such as the World Heritage Chauvet Cave in France (pictured above, top). The reason these pictures are still visible today is the remarkable durability of burnt bone.

"It's a tenacious material," says O'Dohnoghue. "It is black, it absorbs heat but it doesn't degrade. All its calorific value is used up so it doesn't react. It can survive temperatures of 1,400°C."

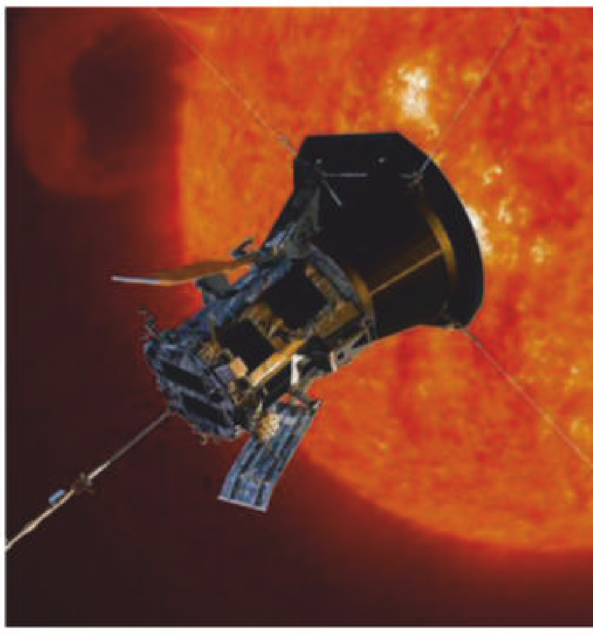
It is that durability that made it the perfect surface for the Solar Orbiter's heat shield.

The finished heat shield should be so efficient that it will dissipate 99.9 per cent of the thermal load it receives from the Sun. While temperatures on its front surface will reach 500°C, at the back it will be just 50°C, allowing the spacecraft's instruments to safely operate at close to room temperature.

The Solar Orbiter is equipped with two groups of instruments. Four *in-situ* instruments will measure ▸



The Solar Orbiter will study the Sun and analyse how the solar wind changes at different distances to Earth's magnetic field



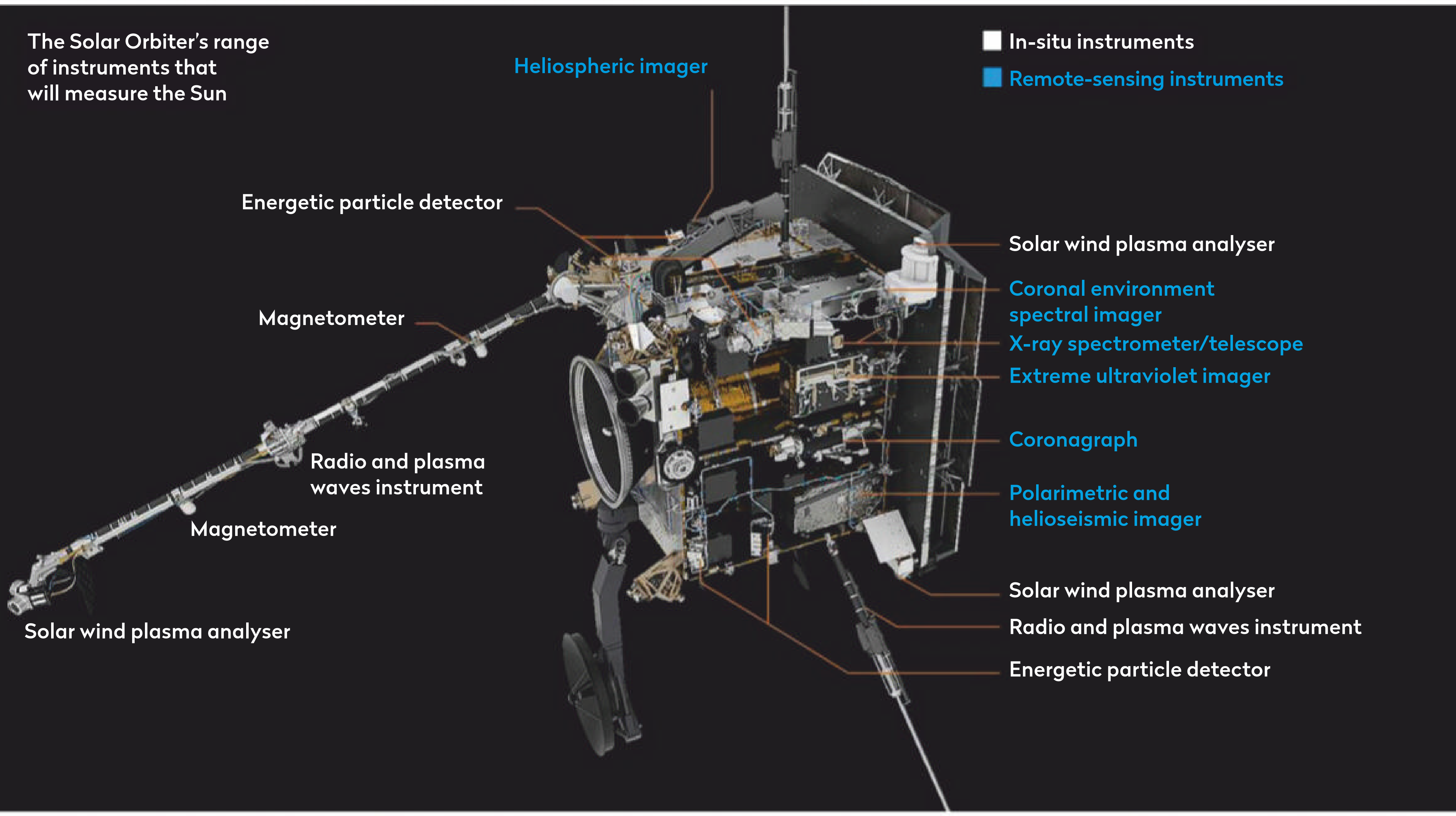
▸ the solar wind in the area immediately around the spacecraft – characterising its make-up and plotting how it changes at different distances from the Sun.

These instruments are mostly fitted to the outside of the spacecraft and on the boom that extends 4.4m behind it. Here, just metres from the blistering temperatures at the front of the heat shield, it will be so cold that the instruments need heating to maintain their operational temperatures.

The other six remote sensing instruments are a selection of cameras and telescopes that will study the Sun itself at a variety of wavelengths. Unfortunately, to see these features the instruments need to look through the heat shield – and so each has a special channel driven through the shield protected by a sliding door which will open only while the instruments are collecting their measurements.

▲ **Solar winds of change:** scientists will use data from the Solar Orbiter (above, top) and the Parker Solar Probe (above) to discover what drives the solar wind

The Solar Orbiter's range of instruments that will measure the Sun



The UK aims for the Sun

Solar Orbiter, an ESA mission with a large UK contribution

The Solar Orbiter spacecraft was designed by Airbus Space Systems and built at their facility in Stevenage. Four of the instruments have UK involvement and two of them are led by British institutions.

The magnetometer was designed and built by a team at Imperial College London to study how the Sun's magnetic field evolves as it spreads through the Solar System. "The Sun's magnetic field drives all of its dynamics," says Prof Tim Horbury, the principal investigator. "It accelerates particles throughout the Solar System. And as the magnetic field flows away From the Sun it controls where the particles go. It is the highway by which particles travel from the Sun to Earth."

The Solar wind plasma analyser will be used to identify which parts of the solar wind are produced by the different features on the Sun's surface. Its principal investigator is Prof Christopher Owen of UCL's Mullard Space Science Laboratory. "A particular process on the Sun will produce a unique fingerprint in terms of how much of each element there might be in the emissions," he says. "Our sensors are able to identify 99.9% of the particle content of the solar wind [and] that will allow us to map back and work out where it comes from."

Solar Orbiter reaches the end of its testing phase in Munich, Germany

The spacecraft's main defence is its heat shield – which will almost always be pointed towards the Sun – leaving the rest of the Solar Orbiter protected in its shadow

The remote instruments will be looking for the source of the solar wind, transient magnetic features on the Sun's surface – like the coronal loops that carry arches of superheated plasma high above the surface and are often the source of the vast eruptions of material known as coronal mass ejections.

Surface features

One of the mission's main aims is to understand how these features develop over time. And so as the spacecraft makes its closest approach each orbit it will match the rotation rate of the Sun, effectively hovering over the same section of the Sun's surface for several days allowing the instruments to observe the surface features as they evolve.

"What I want to know is, how is the magnetic field evolving in the lead-up to coronal mass ejections," says Lucie Green. "The longer we can watch, the better."

Over the course of its mission, the Solar Orbiter should revolutionise our understanding of the solar wind and heliosphere. Especially since it will not be working alone.

NASA also has a spacecraft in close orbit around the Sun. The Parker Solar Probe launched in August 2018 and is on an even more daredevil mission to study the source of the solar wind.

Travelling at 109km/s it is the fastest spacecraft ever built. On 29 January it passed within 20 million km of the Sun's surface, closer than any other spacecraft has been before. By the time it makes its final orbits of the sun in 2025 it will pass within just 6 million km of the solar surface – flying through the outer layers of the corona itself. In these regions, very close to the Sun, the spacecraft will experience temperatures of up to 1,400°C. The radiation will be so intense that it will be impossible to take images of the Sun itself. Instead, the probe will take detailed measurements of the Sun's magnetic field and sample the particles of solar wind at their origin as they are accelerated into the Solar System.

By combining the data from the instruments on both the Solar Orbiter and the Parker Solar Probe, scientists hope to be able to understand how the solar wind is created and controlled, and learn how it develops as it moves away from the Sun.

"The solar wind has a dramatic impact on the rest of the Solar System," says Lucie Green. "The heliosphere really means something for the planets. It's the strong winds in the heliosphere that strip off the atmosphere of Mars and it is the changes in the heliosphere that drive space weather at Earth, and it all starts at the Sun."

Michael Lachmann is a series producer for *The Sky at Night*. He has written and directed programmes with Airbus, which helped build Solar Orbiter

Start with big, easy features then work down to the smaller ones, and don't be afraid of getting lost

Take your Moon OBSERVING FURTHER

Pete Lawrence is your guide to taking your lunar observations to the next level with expert advice on finding your way around its fascinating surface features and more

The Moon is a fascinating object to observe. Big, bright and easy to find, it's sometimes taken for granted in favour of what are perceived as more challenging astronomical targets. Yet, on our doorstep is a rich world just waiting to be explored. In this guide we're going to take a look at some of the aspects which are important for getting the best out of your lunar observing sessions. We'll introduce the basics of getting around the Moon, look at some of the features visible and extend out to see how it interacts with the surrounding sky. So dust off your telescopes, we're going to the Moon!

PETE LAWRENCE

Finding your way

How to get your bearings for your lunar observations

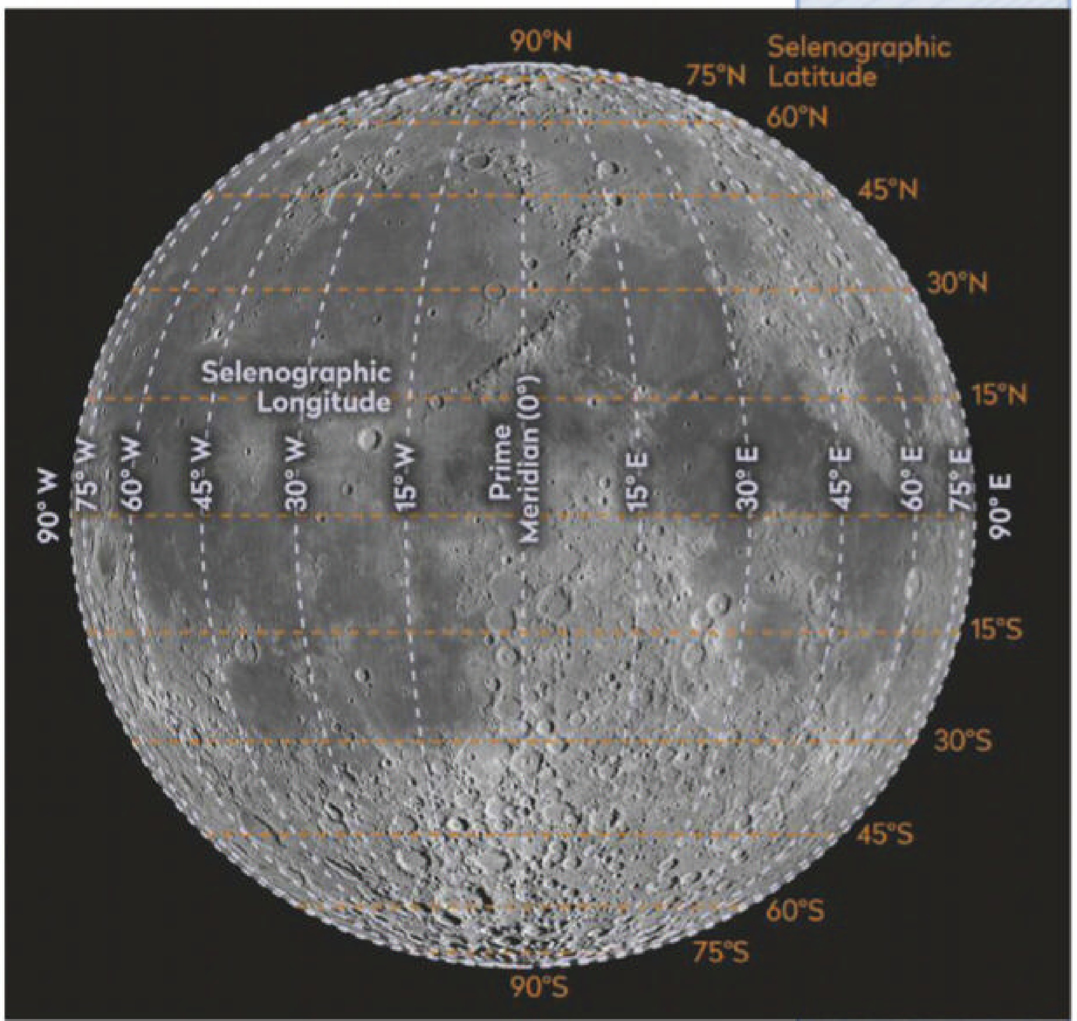
Introducing selenographic latitude and longitude, and lunar prime meridian
Lunar features are located using selenographic latitude and longitude, which are similar to latitude and longitude on Earth ('selenographic' means 'applying to the Moon' in the same way that 'geographic' means 'applying to Earth'. Latitude is measured in degrees north and south of the Moon's equator. Longitude is measured east and west of the lunar prime meridian, a line joining the Moon's north and south poles historically described as passing through crater Mösting A, but now defined as the mean, central north-south line seen from Earth. It doesn't always appear centrally due to the effects of libration.

East becomes west – why the cardinal points on the Moon are different to the rest of the sky
As you look at the Moon's face with north up, east is on the right and west on the left. This is unlike all other Solar System bodies, which take their orientation from the background sky: with north up, east appears on the left. In 1960 the International Astronomical Union flipped the Moon's east to west, to make it more familiar for exploration. Now, if you look at the Moon with north up, it appears as you'd expect it to look if you are looking at a conventional map with west on the left.

Libration – how it affects our view of the Moon
The Moon is tidally locked to Earth; its rotation period is the same as its orbital period and we should only be able to see half its globe. But we see up to 59 per cent of the Moon's surface thanks to libration. This occurs over time in both selenographic latitude and longitude.

PETE LAWRENCE X 4, NASA/GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO X 3


The lunar terminator is the dividing line between lunar night and day



▲ Selenographic latitude and longitude is presented in degrees, in a similar way to Earth

The Moon's orbit is tilted by 5° to the ecliptic plane, so when it appears above this plane we can see further over the southern limb. If the Moon's below it, we see a little over the northern limb. Longitudinal libration is due to its orbit being elliptical. This causes the Earth-Moon distance and the Moon's orbital speed to vary, and lets us see more round the eastern and western limbs.

The Moon's orbit is tilted by 5º to the ecliptic plane, so when it appears above this plane we can see a bit further over its southern limb

The lunar terminator – dividing lunar night and day
Sunlight illuminates half the Moon at any time. It's the Moon's orbital position that dictates how much of this lit hemisphere we see, producing the lunar phases. The dividing line between lunar day (illuminated half) and lunar night (dark half) is the lunar terminator. There are two terminators. The morning one, seen during the waxing phases, marks the transition from lunar night into day; and the evening one, seen during the waning phases, is where lunar day turns into night.

Lunar co-longitude – where the terminator sits
The terminator's position is defined using co-longitude. This value describes the position of the morning terminator in degrees west of the lunar prime meridian, measured 0–360°. The evening terminator's position is equal to the current co-longitude value plus 180°. It isn't addicted by libration. A co-longitude of 0° occurs around first quarter, 90° around full Moon, 180° around last quarter and 270° around new Moon.

What it will look like

What kind of view to expect through the eyepiece of a telescope

▲ **Factors such as seeing conditions and the size of your eyepiece and scope will influence your ability to pick out the Moon's detail**

The Moon is large and close enough to present a surface which can be explored with the naked eye, binoculars or through a telescope. To the naked eye and binoculars, the Moon's orientation with north up offers west on the left and east on the right. Through a scope, its orientation will vary depending what arrangement you have at the eyepiece and on the type of telescope.

The Moon's surface shows lots of fine detail, especially when the terminator is nearby. The ability to resolve detail depends on the size of your telescope, seeing conditions and using an appropriate magnification. You can use a simple formula to work out a telescope's resolving power in arcseconds: $R = 120 \div d$, where d is the diameter of your telescope in mm. This is known as the Dawes' limit and it can be converted to an approximate physical dimension, knowing that the Moon's diameter is 3,474km and its angular size is approximately 1,800 arcseconds, and therefore each arcsecond represents 1.93km. The smallest physical feature (p) your telescope should resolve is given as $p = 1.93 \times (120 \div d)$ *km*. So a 200mm scope should resolve 1.93 x (120 ÷ 200) = 1.2km features, while a 350mm scope should resolve down to 700m.

As light passes through Earth's atmosphere it is bent or refracted by air. Variations in the density and temperature of fast-moving regions of air produce variations in the degree of refraction, an effect known as astronomical seeing. This ranges from perfect stillness to major instability when features look like a blurred fuzz through the eyepiece. Good seeing tends to occur with the Moon higher in the sky as its light has less atmosphere to pass through.

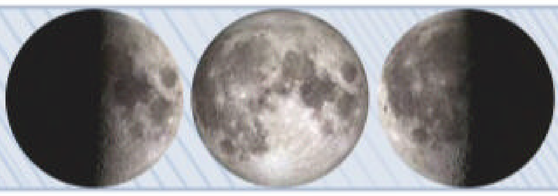
▲ **The method used to observe the Moon will change how it appears.**
1 Naked eye and binocular view
2 Telescope view (rotated through 180°)
3 Star diagonal view (flipped horizontally)

Fine tuning your observations

Your telescope has its own seeing micro-climate too. Move it from a warm room into a cold garden and the temperature inequality will create internal tube-currents which will spoil the view. So it's essential to let it cool to an equilibrium condition. Cooling times will vary from 30 minutes up to several hours depending on your scope's size.

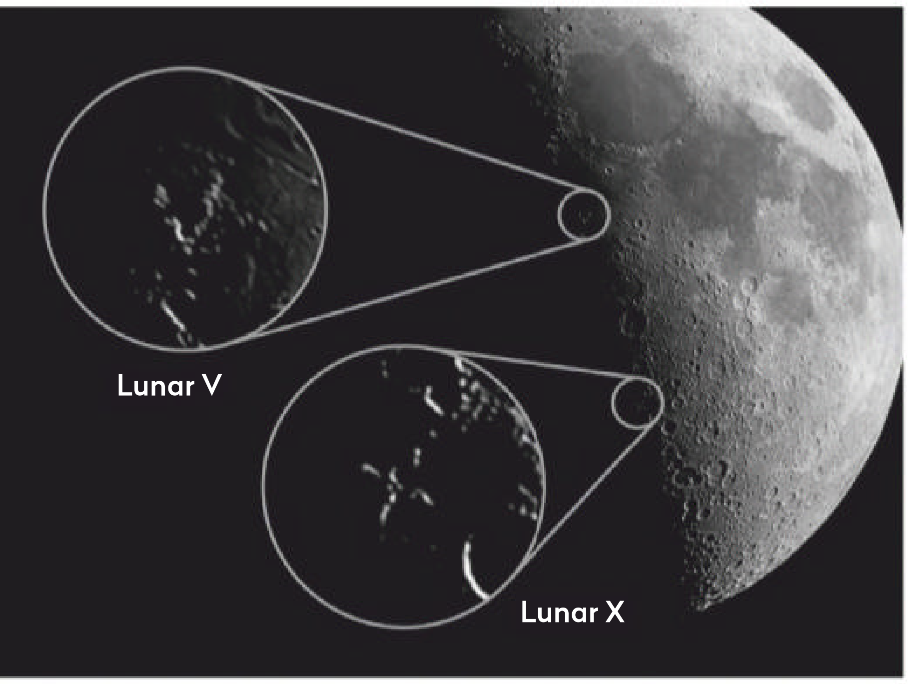
The eyepiece choice determines your telescope's magnifying power, calculated by dividing your scope's focal length by the eyepiece's focal length, using the same units. Start with a low power and increase magnification until the view becomes mushy, then step back to the last eyepiece which gave a crisp view.

The Moon has many detailed features which look best when the Sun is low in the lunar sky, which occurs when the terminator is nearby. Full Moon appears tempting but is the worst time to look because there are hardly any shadows. As the terminator creeps across the lunar surface, shadows change. As a result, the Moon always appears to offer something new. ▸

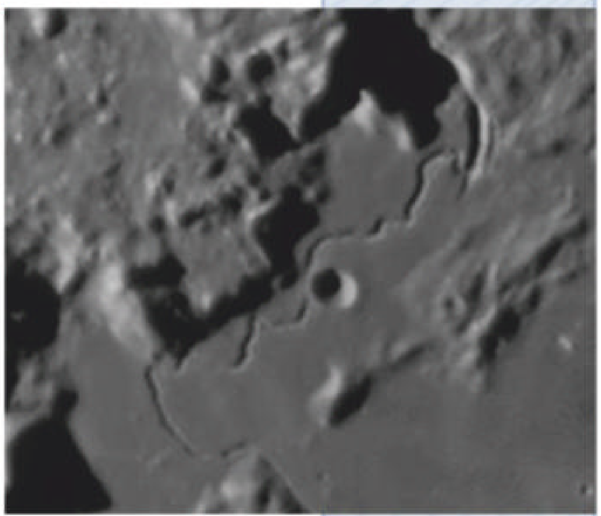


Targets to observe

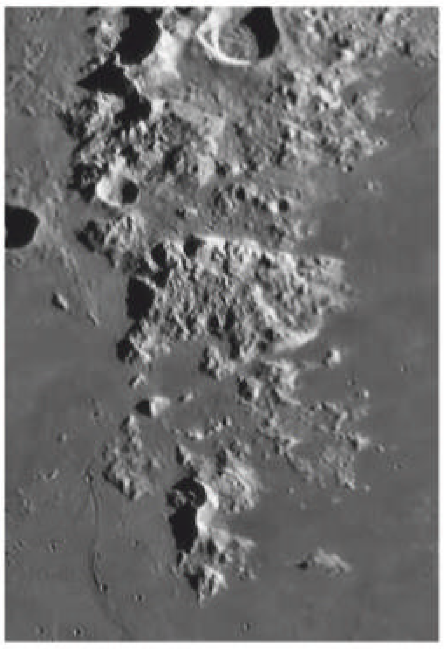
A telescope will reveal the Moon's geology and landscapes



Rilles ▶
Rilles are cracks in the Moon's surface. They can be subdivided into linear, sinuous and arcuate types. They are often narrow but can extend for many hundreds of kilometres, with some being isolated and others forming part of an intricate network. They're accentuated when the terminator is nearby.

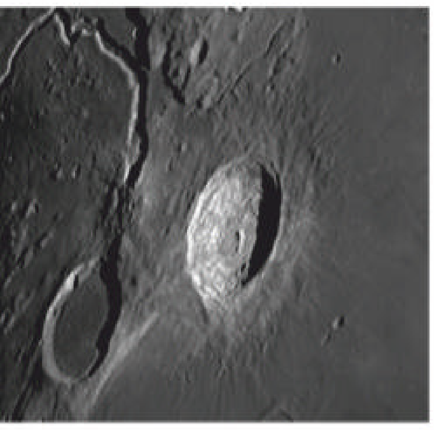


▲ Clair-obscur effects
Clair-obscur effects are when light and shadow areas on the Moon's surface appear as something familiar. They're often time-critical and only appear when the terminator is at a specific co-longitude when the Moon is above the horizon. Popular examples are the Lunar X and V, when it looks as if there are two giant letters visible on the lunar terminator. Others are more intricate and difficult to glimpse, such as Cassini's Moon Maiden, Gruithuisen's Lunar City and the Face in Albategnius.



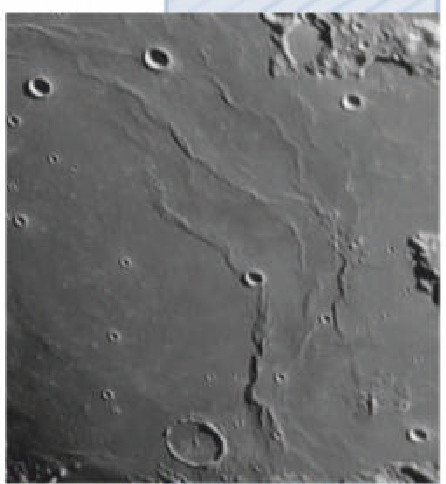
◀ Mountains
There are many mountains on the Moon's surface. Some are isolated while others belong to ranges like the lunar Apennines, which border the eastern edge of Mare Imbrium. With the terminator close by, the shadows of lunar mountains are impressive.

Rays from crater Tycho extend more than half way around the Moon

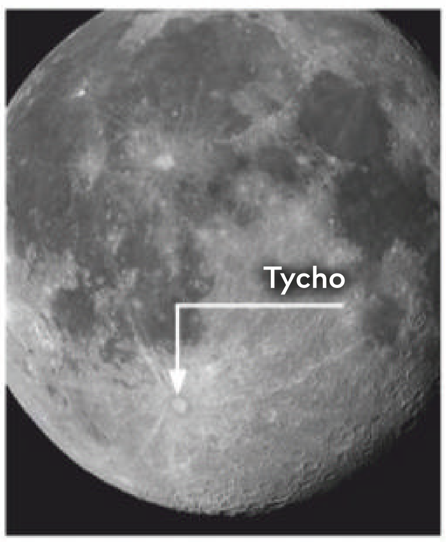


◀ Banded craters
Craters that appear to have dark or light radial lines within their walls are known as 'banded craters'. There are many of them visible across the Moon's disc. Typically small in size, they're great for observing with a telescope and of interest to organisations such as ALPO via their Banded Crater Program. See **http://moon.scopesandscapes.com/alpo-bcp.htm**

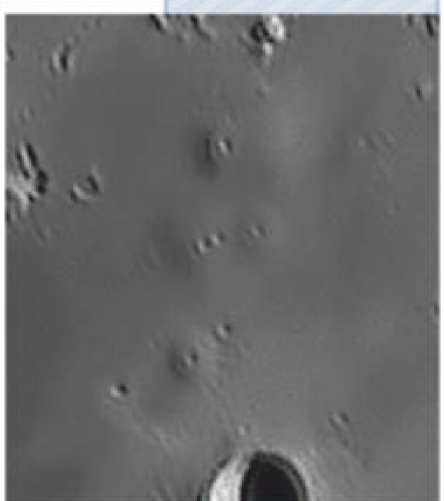
Wrinkle Ridges ▶
As the lava-filled lunar seas cooled, surfaces buckled and ridges formed. These are hard to see at full Moon when lit from above, but when the terminator is near and they're obliquely lit they take on a defined, complex appearance. They can run for hundreds of kilometres.



Ray craters ▶
Ray craters are young, bright features on the lunar surface, formed from impacts throwing material across the surrounding terrain. Tracing how far rays extend across the lunar surface is a fascinating task and often quite surprising. Rays from crater Tycho for example, extend more than half-way around the Moon.



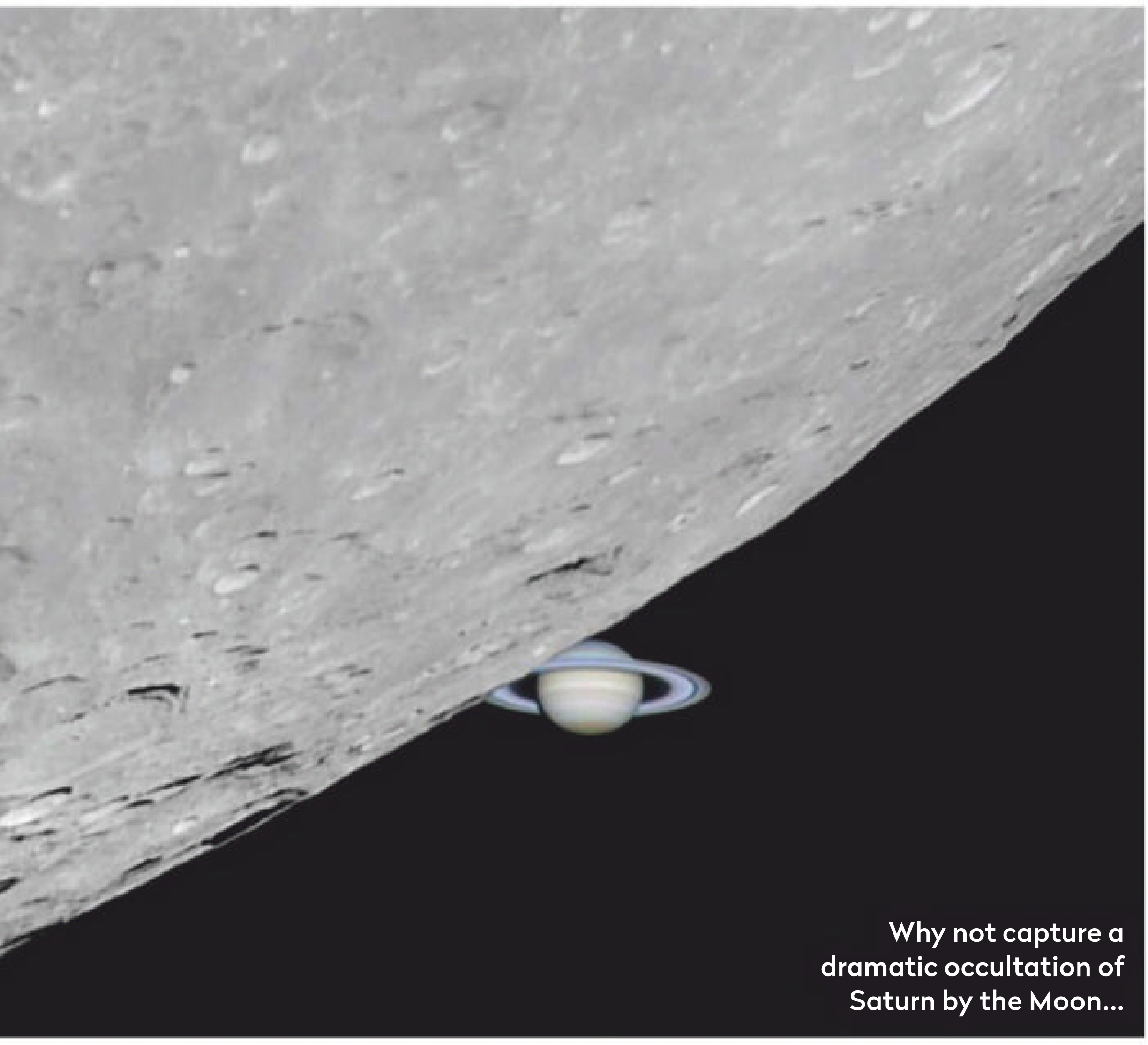
Domes ▶
Most features visible on the Moon's surface have impact origins, but there is evidence of volcanic activity. Shield volcanos appear as domes, sometimes with tiny summit pits. These can be a challenge; look for them when the terminator is nearby. Good seeing and a high-power eyepiece also help.



PETE LAWRENCE X 9, NASA/GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO X 3

Lunar occultations

Time when stars go behind the Moon, and see them graze the uneven edge



Why not capture a dramatic occultation of Saturn by the Moon...

Pete Lawrence is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four

When the Moon is in its fuller phases, it can appear large and dominant. However, in reality it's quite a small object in the sky, around just half-a-degree across. Compare it to the width of your little finger at arm's length, which will cover it easily.

As it moves around the sky, the Moon covers background stars in events called lunar occultations. Timing these events used to be very important for working out the position of the Moon and the profile shape of its edge. As it's small, a lunar occultation of a bright star or planet isn't that common. Occultations of dim stars do happen reasonably frequently though.

As the Moon moves east across the sky, occultations caused by a waxing Moon have the background object disappearing behind the Moon's dark, night edge. These can be challenging to observe because the position of the dark edge is not always obvious. The best technique is to simply keep looking. As stars are point sources of light and the Moon has no atmosphere, disappearance will be fast and it's not uncommon to miss such an event due to blinking! Reappearance for a waxing lunar occultation occurs from behind the Moon's bright edge. This is equally as challenging because you're never completely sure you're looking at precisely the right part of the limb. Occultations involving waning lunar phases exhibit the reverse situation; disappearance behind the bright limb and reappearance from behind the dark limb.

Look for a grazing occultation

The Moon is much closer than the background stars and its position against those stars varies slightly depending on your location on Earth. From a very specific path it's sometimes possible to see a star 'graze' along the upper or lower edge of the Moon. This event is known as a grazing occultation and, if you're lucky, can be quite a spectacle, with the star disappearing behind lunar peaks and reappearing within valleys and depressions on the lunar limb.

Predictions for grazing occultations can be found online or via publications such as the *BAA Handbook*.

The timing of occultations is a particularly satisfying observation to make and these days is easier than ever to achieve. Multiple lap-timing stopwatch apps can be installed on a laptop or tablet to record the disappearance and reappearance events. Synchronise your timer with a recognised internet time server just prior to recording to ensure the highest possible accuracy.

...or the Moon occulting the Pleiades cluster, M45

ROYAL MUSEUMS GREENWICH
rmg.co.uk/astrophoto
20% off with code SKY20
Quote by phone or at admissions desks
Major exhibition
Insight Investment
Astronomy Photographer of the Year
Now open at the National Maritime Museum
#astrophoto2019
Royal Museums Greenwich
National Maritime Museum | Royal Observatory | Cutty Sark | The Queen's House
Cutty Sark
Greenwich (only 8 mins from London Bridge)
Greenwich Pier
Sponsored by
Insight INVESTMENT
BNY MELLON | INVESTMENT MANAGEMENT
Media partner
BBC Sky at Night MAGAZINE
Cosmic Plughole © James Stone

16-PAGE CENTRE PULLOUT

BBC Sky at Night MAGAZINE

The Sky Guide

MARCH 2020

A CONJUNCTION OF JUPITER & MARS

Observe the morning meeting of these planets, which form a trio with Saturn

PETE LAWRENCE

VENUS AT SUNSET

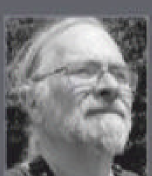
See the bright planet dominating the evening sky

EARTHSHINE EXPLAINED

The phenomenon that reveals the Moon's dark side

About the writers

Astronomy expert **Pete Lawrence** is a skilled astro imager and a presenter on *The Sky at Night* monthly on BBC Four



Steve Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 54

Also on view this month…

- ✦ Asteroid 27 Euterpe reaches opposition
- ✦ The Moon's crater Jacobi in the southern highlands
- ✦ Can you spot a meeting of Mars and Pluto?

Red light friendly

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

Get the Sky Guide weekly

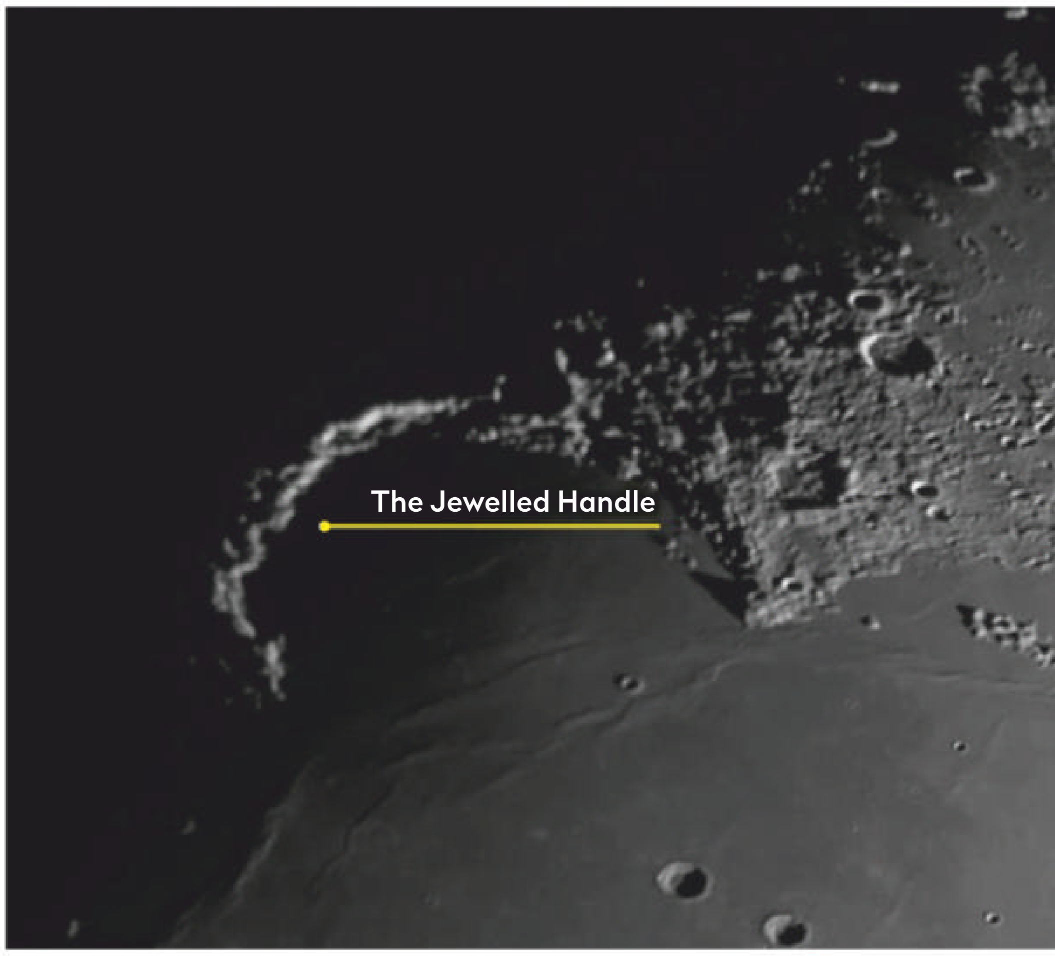
For weekly updates on what to look out for in the night sky and more, sign up to our newsletter at **www.skyatnightmagazine.com**

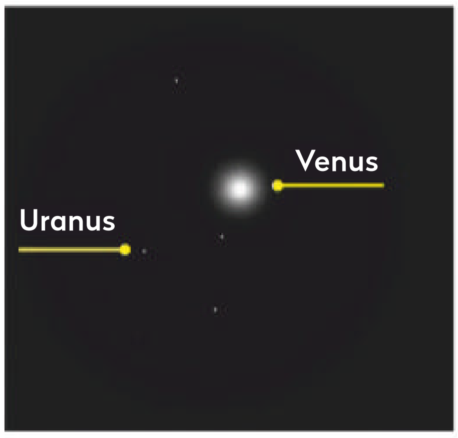
MARCH HIGHLIGHTS

Your guide to the night sky this month

Monday 2 This evening's first quarter Moon sits just to the west of the V-shaped Hyades open cluster. The bright star 4° southwest of the Moon is Aldebaran (Alpha (α) Tauri). At 20:30 UT the Moon is 48 arcminutes north of sixth magnitude open cluster NGC 1647.

Wednesday ▶ 4 The clair-obscur effect known as the Jewelled Handle is visible on the Moon this afternoon at around 16:20 UT. This occurs when the lunar dawn illuminates the peaks of the curving Jura mountain range bordering Sinus Iridum, the Bay of Rainbows.





◀ Sunday 8 This evening the planet Uranus will lie 2.2° from blazing Venus. There's quite a difference in magnitudes here with Venus shining at mag. –4.2 and Uranus at mag. +5.9, an 11,000 fold difference in brightness.

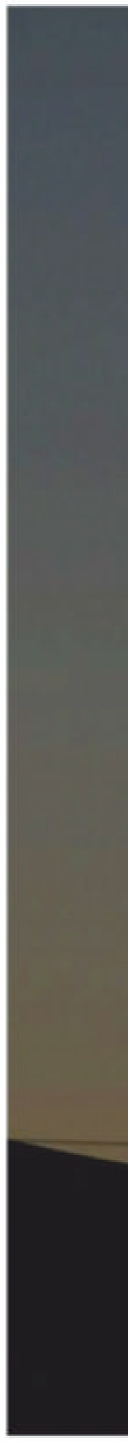
Wednesday 18 This morning sees a 31%-lit waning crescent Moon near to mag. +0.9 Mars and mag. –1.9 Jupiter. All three appear close together as they rise above the southeast horizon around 04:15 UT.

Thursday 19 This morning's 22%-lit waning crescent Moon sits 4° to the southeast of mag. +1.0 Saturn.

Friday 20 Today the Sun crosses the celestial equator heading north – the Northern Hemisphere's spring equinox.

This morning mag. –1.9 Jupiter is 43 arcminutes north of mag. +0.9 Mars. Saturn lies 7.1° east of the pairing.

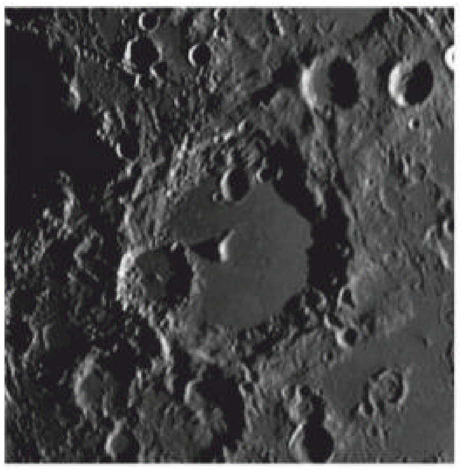
Saturday ▶ 21 Early risers will see a slender 8%-lit waning crescent Moon 7.7° from mag. +0.4 Mercury. Both objects are visible in the dawn twilight, low above the south-southeast horizon around 20 minutes before sunrise.



◀ Friday 27 Venus reaches dichotomy, when its phase should appear 50%-lit. In reality this occurs visually a few days earlier due to the Schröter Effect.

Saturday 28 This evening's sky plays host to mag. –4.3 Venus, a 17%-lit waxing crescent Moon and the Pleiades open cluster, M45, all appearing close to one another – a fantastic opportunity for a photograph.

Tuesday ▶ 31 The clair-obscur effect known as The Face in Albategnius is visible on this evening's Moon. Look at the crater Albategnius and see whether you can see a human profile on the rim shadow that falls upon its floor.



PETE LAWRENCE X 7

Friday ▶

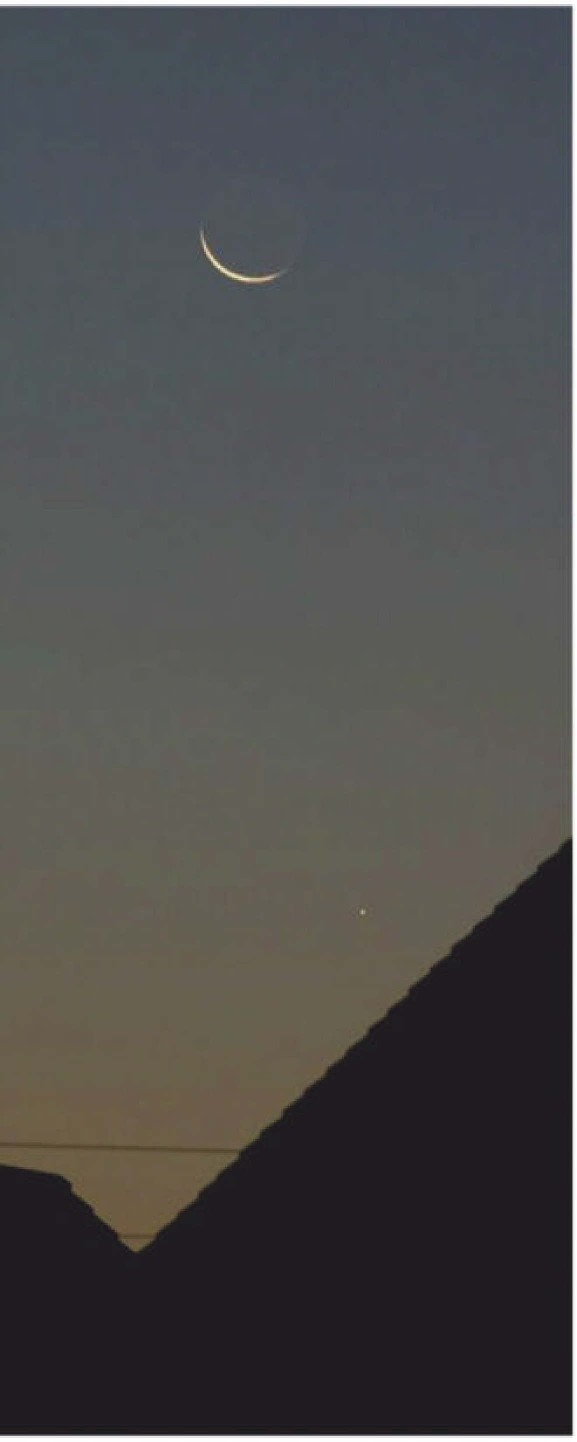
6 There's a challenge for astrophotographers this evening as the 88%-lit waxing gibbous Moon passes across the northern part of open cluster M44, the Beehive. See page 47 for more.

Monday

9 Today's full Moon occurs at 17:48 UT, 12 hours and 45 minutes before the Moon reaches perigee, the closest point in its orbit around Earth. It will appear slightly larger and brighter than an average full Moon and is what some call a supermoon.

Tuesday

17 The clair-obscur effect known as the Lunar 2 is visible on this morning's slightly less than last quarter Moon. The effect produces a distinct '2' at the eastern sections of craters Deluc and Deluc D, near the Moon's southern limb.



Monday

23 If you fancy a challenge, this morning, the mag. +0.9 planet Mars lies just 2 arcminutes southwest of mag. +14.4 Pluto. They get to within 48 arcseconds of each other, but Pluto will be lost in a brightening sky. View shortly after rising around 04:00 UT.

Thursday

26 This morning sees mag. +0.9 Saturn, mag. +0.8 Mars and mag. –2.0 Jupiter all sitting in a triangular formation, low in the southeast as the dawn twilight begins to take hold.

Sunday

29 The start of British Summer Time (BST). The clocks advance by one hour at 01:00 UT to become 02:00 BST.

Monday

30 Last chance to see this month's *Moonwatch* target, the crater Jacobi, under optimum conditions. The crater is near the terminator on 1 and 30 March in the evening sky, and on 15 and 16 March in the morning sky. See page 52.

Family stargazing

At the start of March, Orion the Hunter can be seen south-southwest as darkness falls and low in the west-southwest at the month's end. He's easy to recognise thanks to the three similar stars in a line which form his Belt. Find Betelgeuse; it's the orange star in the upper-left (northeast) corner of the main pattern. Explain to youngsters that it's a red-supergiant star that's around 1,000 times larger than our Sun. Appearing dimmer than normal, Betelgeuse is entering the last stages of star life. It's expected to explode as a supernova in the next 100,000 years. **www.bbc.co.uk/cbeebies/shows/stargazing**

NEED TO KNOW

The terms and symbols used in The Sky Guide

Universal time (UT) and British Summer Time (BST)
Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT

RA (Right ascension) and dec. (declination)
These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'

Family friendly
Objects marked with this icon are perfect for showing to children

Naked eye
Allow 20 minutes for your eyes to become dark-adapted

Photo opp
Use a CCD, planetary camera or standard DSLR

Binoculars
10x50 recommended

Small/ medium scope
Reflector/SCT under 6 inches, refractor under 4 inches

Large scope
Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

If you're new to astronomy, you'll find two essential reads on our website. Visit **http://bit.ly/10_easylessons** for our 10-step guide to getting started and **http://bit.ly/buy_scope** for advice on choosing a scope

THE BIG THREE The three top sights to observe or image this month

▲ Early risers will be rewarded with views of Jupiter, Saturn and Mars in beautiful close approaches in mornings throughout the month

DON'T MISS

MORNING PLANETS

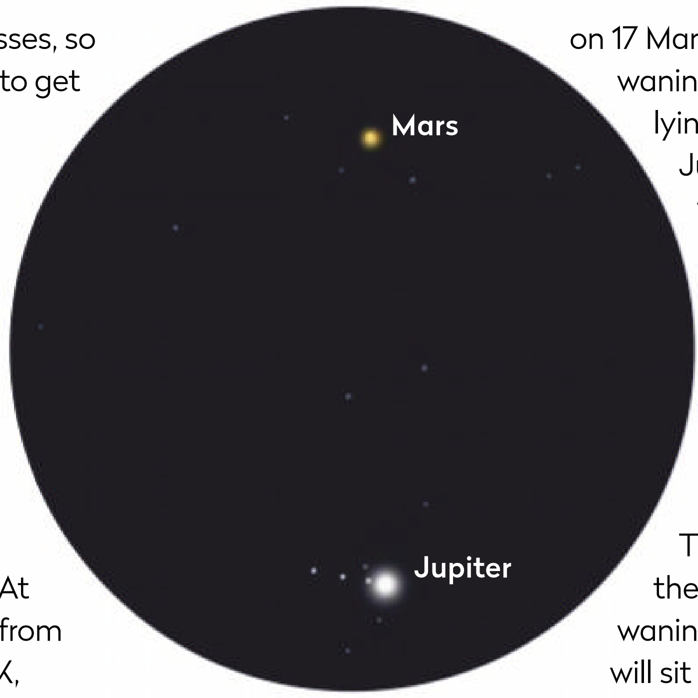
BEST TIME TO SEE: All month. Mars-Jupiter close conjunction on 20 March, Mars-Saturn conjunction on 31 March

While Venus steals the show by quite some margin in this month's evening sky, there's plenty happening in the pre-dawn morning twilight too: the three planets Mars, Jupiter and Saturn all appear together low in the southeast.

As dawn is breaking at the start of March, all three appear in a line, visible low in the southeast. Mag. +1.1 Mars appears more first, followed by mag. –1.8 Jupiter and mag. +1.0 Saturn. An interesting exercise is to compare the colours of Mars and Saturn, which are a similar brightness. Mars has a definite orange hue, while Saturn is more off-white.

As March progresses, so the mornings start to get lighter and this doesn't help the situation. However, with slight timing adjustments, it will still be possible to see the trio right up to the end of the month as long as you have a flat southeast horizon. At the start of March, from the centre of the UK, all three planets will be above the horizon in brightening skies around 06:00 UT. At the month's end you'll need to set the alarm earlier, with all three visible above the southeast horizon around 04:30 UT. Remember the clocks go forward on 29 March, which will mean you get an extra hour lie-in right at the end of the month.

Mars slowly draws closer to Jupiter throughout much of the month, lying just 43 arcminutes from the gas giant on the morning of 20 March. Just before this, don't miss the monthly Moon pass which begins on 17 March with a 41%-lit waning crescent Moon lying 15.4˚ west of Jupiter. On 18 March, the now 31%-lit waning crescent Moon nestles in close to Mars and Jupiter. Mars will have brightened slightly on this date to mag. +0.9. Then on 19 March, the now 22%-lit waning crescent Moon will sit 4˚ southeast of Saturn, rising as the sky starts to get quite bright.



▲ Catch Jupiter and Mars after 04:00 UT low above the southeast horizon on 20 March (inverted telescope view with south up)

On the morning of 31 March, it's Saturn and Mars which appear as a close pair. Not to be outshone by beautiful Saturn, Mars will have brightened to mag. +0.8 with Saturn sticking at +0.9. Both planets appear separated by a fraction under a degree on this date.

The appearance of the 'line' on 1 March changes noticeably during the month. On 31 March all three planets form a pointed isosceles triangle with Jupiter at the tip, and Mars and Saturn forming the base.

ALL PICTURES: PETE LAWRENCE

Moon moving through M44

BEST TIME TO SEE: Evening of 6 March

Waxing gibbous Moon near the Beehive, M44, in 2019. This month the Moon will pass north of the cluster

The Moon is constrained in the sky. Although it follows the ecliptic – the apparent path of the Sun against the stars, which represents the plane of Earth's orbit – it can occupy a slightly wider corridor thanks to having an orbit inclined to the ecliptic plane by 5°.

This corridor includes a number of bright stars and many faint ones. It also includes the planets, although lunar interactions with them are pretty infrequent. In addition, it also includes several bright deep-sky objects. On 6 March, a bright 88%-lit waxing gibbous Moon will pass just north of the Beehive Cluster, M44, which lies at the heart of the constellation of Cancer, the Crab.

The degree of closeness you get will depend on where you live. The Moon is close enough to Earth to show parallax. If you live in the far south of the UK, the Moon appears a fraction further north of the cluster. Those in the far north, however, will get to see it skirt the edge of the Beehive. Closest approach will be around 22:00 UT, wherever your location.

To the naked eye the Beehive is pretty faint and only visible from a dark site. With the Moon next door, it'll be washed out completely. You'll fare better with binoculars or a telescope using a low power eyepiece. If you're into photography, try to capture the Moon and the cluster stars in one shot. It's a real challenge but great fun to try.

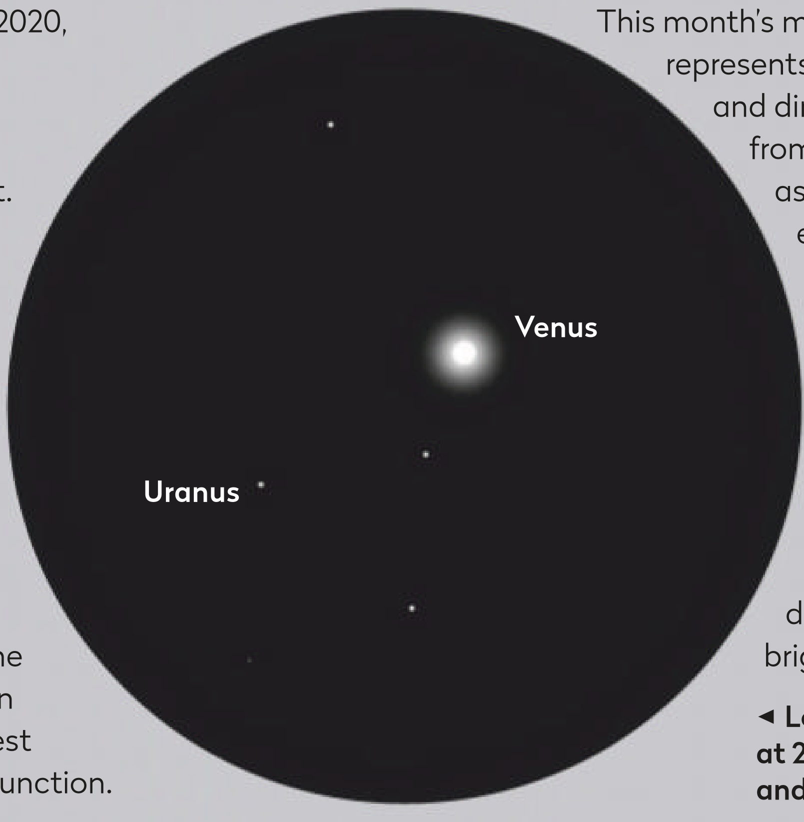
There are several dim stars to the north of M44 which will be occulted by the Moon on this date. The brightest of these is mag. +6.7 HIP 42628 which disappears around 21:30 UT on 6 March, reappearing again around 10:40 UT. These times are for the centre of the UK and will vary with location. The best strategy is to start observing at least 15 minutes earlier than the stated times.

Uranus and Venus

BEST TIME TO SEE: 7–9 March around 20:00 UT. Closest approach 8 March

On the evening of 27 January 2020, Venus had a conjunction with Neptune. On that occasion, as both objects approached setting, they appeared around 4 arcminutes apart. Since then Venus has moved east against the background stars and this month it's the turn of Uranus to get a visit. The separation and brightness levels of both planets makes this an ideal target for binoculars.

This meeting won't be as close, with Venus passing Uranus by 2.2° on the evening of 8 March. The meeting between Venus and Neptune at the end of January saw a situation where both the brightest and dimmest planets seen from Earth were in conjunction.



This month's meeting between Venus and Uranus represents a conjunction between the brightest and dimmest planets which can be seen from Earth using the naked eye. However, as Uranus is on the threshold of naked-eye visibility, this definition might be stretching it a bit.

This particular meeting is quite favourable, with both objects being around 20° altitude up as true darkness falls. Venus is of course much brighter than Uranus, the magnitudes being –4.2 and +5.9 respectively. In terms of brightness difference, Venus is 11,000 times brighter than Uranus.

◄ **Look through 7x50 binoculars on 8 March at 20:00 UT for a conjunction of the bright and dim planets, Venus and Uranus**

THE PLANETS Our celestial neighbourhood in March

PICK OF THE MONTH

Venus

Best time to see: 31 March, shortly after sunset
Altitude: 35°
Location: Taurus
Direction: West
Features: Phase, subtle markings
Recommended equipment: 75mm or larger

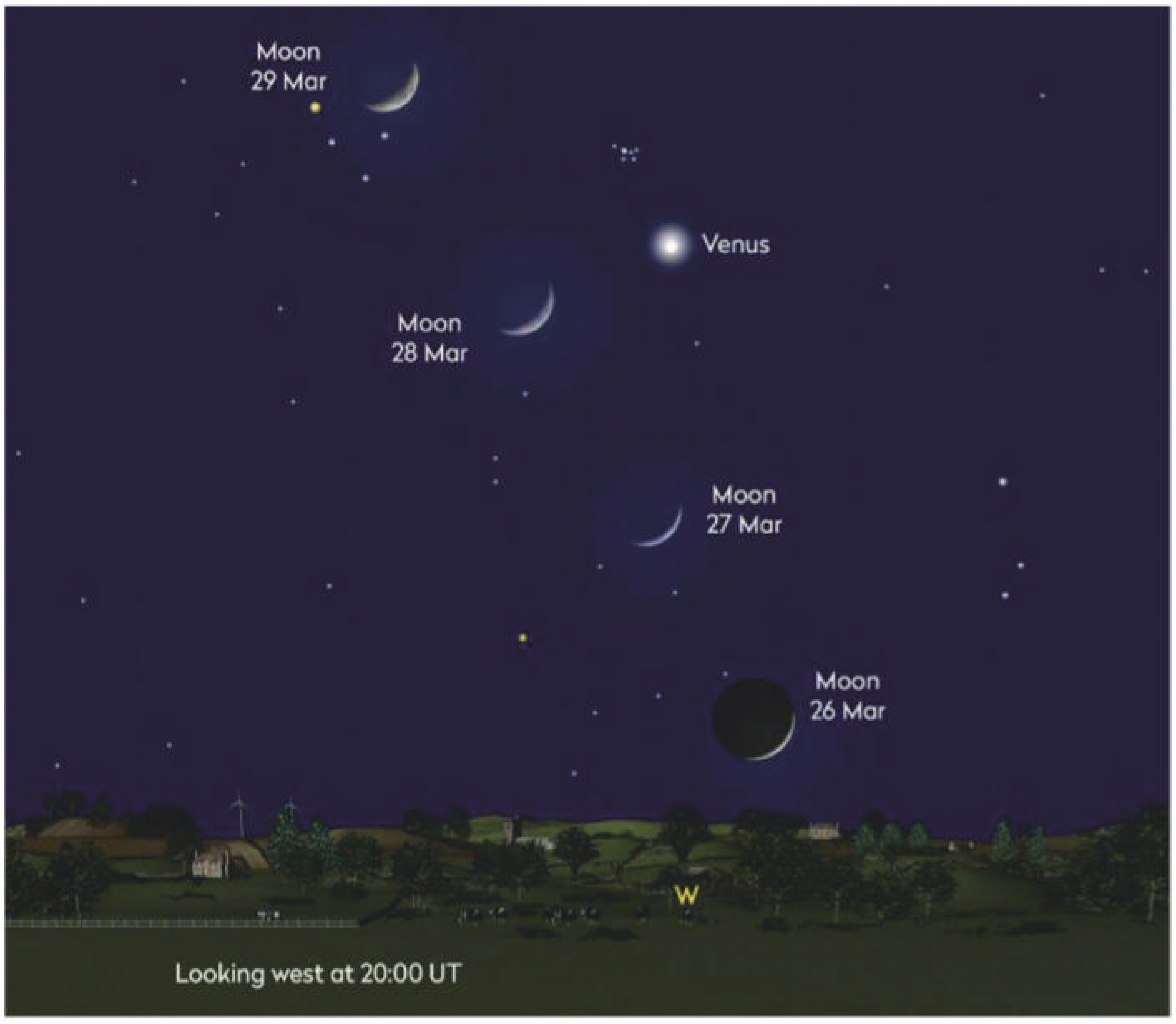
Venus currently dominates the evening twilight. It reaches greatest eastern elongation on 24 March, separated from the Sun by 46°. Telescopically, the planet presents an 18 arcsecond disc, 62%-illuminated on 1 March. At the start of the month it sets 4 hours and 20 minutes after the Sun. On 9 March, mag. –4.1 Venus appears 2.5° north of mag. +5.9 Uranus.

By the end of the month, Venus remains above the horizon after sunset for nearly five hours, appearing against a truly dark sky for nearly three hours. As the end of the month approaches, Venus appears to track ever closer toward the Pleiades open cluster, a prelude to a spectacular passage across the cluster early in April.

Venus reaches dichotomy in March, the term used to describe when it appears with a 50% phase seen through the eyepiece. Although expected on 27 March, during evening apparitions the 50% phase typically occurs a few days earlier than predicted by geometry. This is known as the Schröter effect and is an anomaly believed to occur because of the way Venus's thick atmosphere scatters light. Phase estimates are easy to do. Simply estimate how far the terminator stretches across the planet as a percentage of its diameter.

This month's Moon-Venus conjunction occurs on 28 March, when a 16%-lit waxing lunar crescent appears 7.2° south of the planet. This occurs when both the Moon and Venus are relatively close to the Pleiades, a situation which enhances the photographic attraction of the scene.

By 31 March, Venus appears through the eyepiece with an angular size of 25 arcseconds and a phase of 47%. The planet's magnitude increases to –4.3 by the end of March.

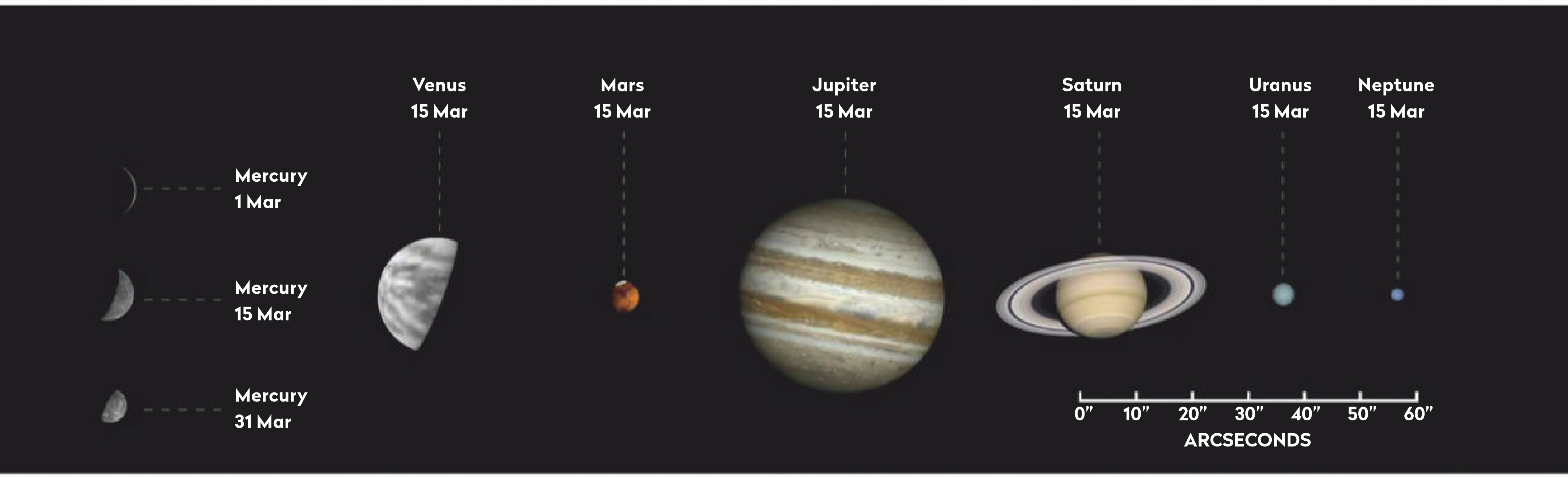


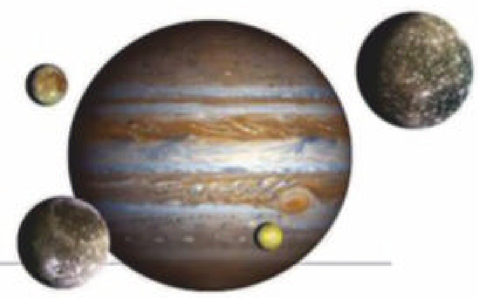
▲ **Venus and the waxing crescent Moon will put on a stunning show this month**

PETE LAWRENCE X 3

The planets in March

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope





Mercury

Best time to see: 15 March, 30 minutes before sunrise
Altitude: 2° (very low)
Location: Aquarius
Direction: East-southeast
Mercury is a morning object low in the east-southeast mid-month. A balancing act then takes place: as the planet becomes brighter it drops south beneath the ecliptic and loses altitude. It reaches greatest western elongation on 24 March (27.8°) but will only be visible for a short time before the sunrise.

Mars

Best time to see: 19 March, around 05:00 UT
Altitude: 6° (low)
Location: Sagittarius
Direction: Southeast
Slowly improving in apparent size and brightness, morning planet Mars remains low from the UK. It appears to jostle for position with Jupiter and Saturn over the month, a close 43 arcminute conjunction with Jupiter occurring on 20 March and a 1° separation from Saturn on the 31st. Mars remains tiny through the eyepiece, with a disc just 5 arcseconds across. At this size only large-scale markings can be seen on the planet's surface.

The planet's brightness increases from mag. +1.1 on 1 March to mag. +0.9 on the 31st.

Jupiter

Best time to see: 31 March, 04:40 UT
Altitude: 8° (low)
Location: Sagittarius
Direction: Southeast
Jupiter is visible low in the southeast morning sky in brightening dawn twilight. It sits close to Mars and Saturn, having a close conjunction with Mars on 20 March. It shines at mag. –1.8 at the month's start, brightening to mag. –2.0 by the month's end. All three planets are close to the most southerly position they can attain in the sky and this means that any telescopic view of them is likely to be compromised due to poor atmospheric stability, which occurs at low altitude. This may limit high magnification views from the UK, but the naked-eye show is still remarkable to witness. See page 46.

Saturn

Best time to see: 31 March
Altitude: 6° (low)
Location: Sagittarius
Direction: Southeast
Saturn is close to Mars and Jupiter this month, all three planets lying within Sagittarius. It's similar in brightness to Mars, at mag. +0.9 and lies close to the Red Planet on 31 March, appearing 1° to its north. This is a good opportunity to compare the colours of both planets. Mars appears to have an orange hue, while Saturn is off-white.

Uranus

Best time to see: 8 March, 20:00 UT
Altitude: 22°
Location: Aries
Direction: West
Uranus is now a compromised planet, appearing to the west of south with diminishing altitude as the sky gets dark. It still has a decent altitude against dark skies at the start of March, but this degrades. On 8 March this distant ice giant appears just 2.2° from mag. –4.2 Venus. See page 46.

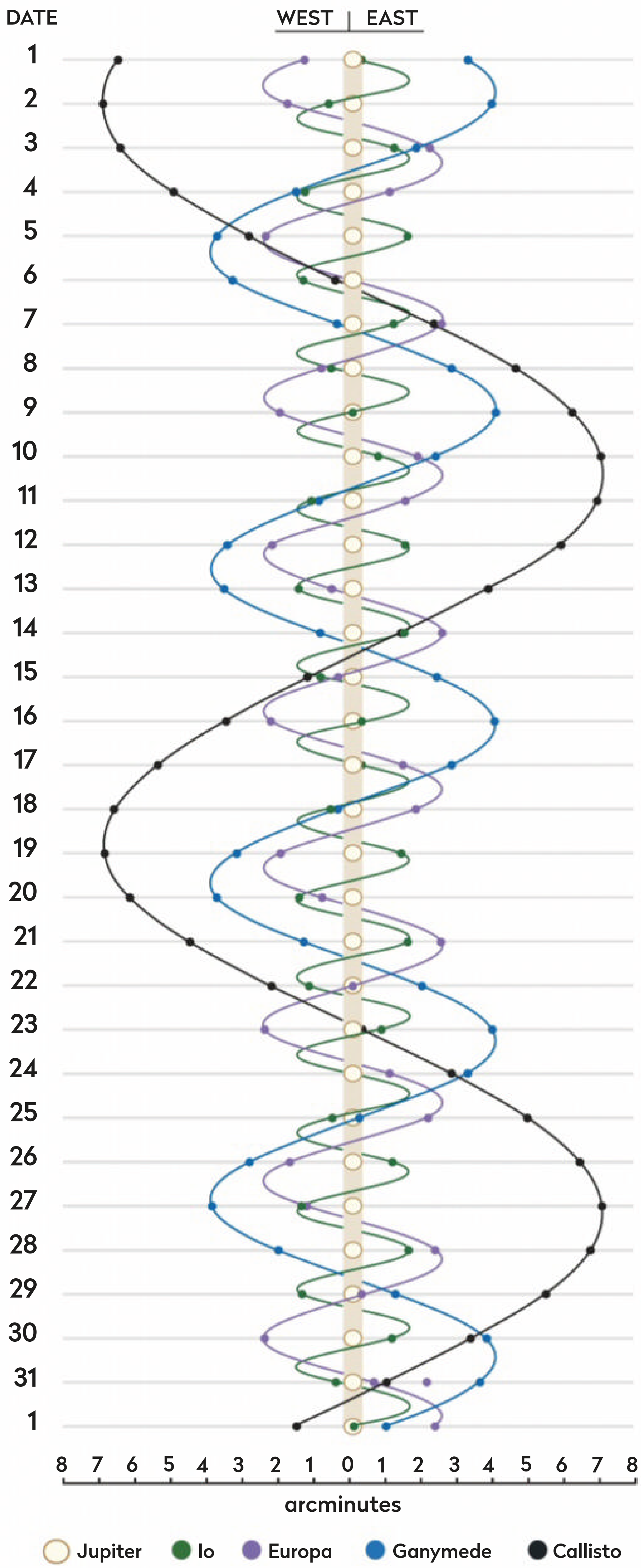
NOT VISIBLE THIS MONTH:
Neptune

Neptune is in conjunction with the Sun on 8 March and is not currently visible.

More **ONLINE**
Print out observing forms for recording planetary events

JUPITER'S MOONS: MARCH

Using a small scope you can spot Jupiter's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 00:00 UT.



THE NIGHT SKY – MARCH

Explore the celestial sphere with our Northern Hemisphere all-sky chart

KEY TO STAR CHARTS

Arcturus	STAR NAME
PERSEUS	CONSTELLATION NAME
	GALAXY
	OPEN CLUSTER
	GLOBULAR CLUSTER
	PLANETARY NEBULA
	DIFFUSE NEBULOSITY
	DOUBLE STAR
	VARIABLE STAR
	THE MOON, SHOWING PHASE
	COMET TRACK
	ASTEROID TRACK
	STAR-HOPPING PATH
	METEOR RADIANT
Circlet	ASTERISM
	PLANET
	QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

N E S W — COMPASS AND FIELD OF VIEW

MILKY WAY

CHART: PETE LAWRENCE

When to use this chart

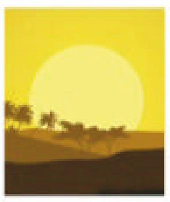
1 March at 00:00 UT
15 March at 23:00 UT
31 March at 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

How to use this chart

1. Hold the chart so the direction you're facing is at the bottom.
2. The lower half of the chart shows the sky ahead of you.
3. The centre of the chart is the point directly over your head.

Sunrise/sunset in March*



Date	Sunrise	Sunset
1 Mar 2020	06:57 UT	17:49 UT
11 Mar 2020	06:33 UT	18:08 UT
21 Mar 2020	06:09 UT	18:26 UT
31 Mar 2020	06:45 BST	19:44 BST

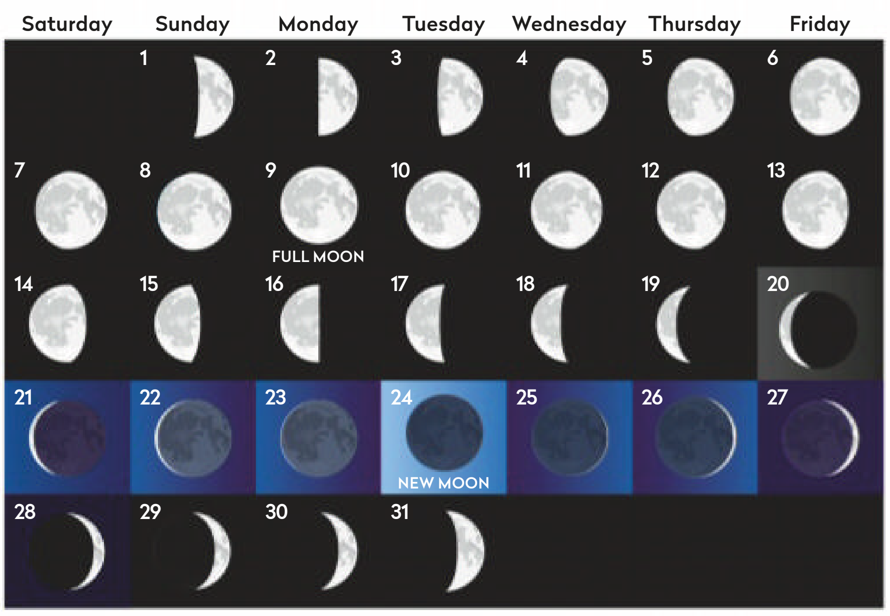
Moonrise in March*

Moonrise times

1 Mar 2020, 09:37 UT	17 Mar 2020, 03:19 UT
5 Mar 2020, 12:12 UT	21 Mar 2020, 05:48 UT
9 Mar 2020, 17:42 UT	25 Mar 2020, 06:53 UT
13 Mar 2020, 23:37 UT	29 Mar 2020, 09:03 BST

*Times correct for the centre of the UK

Lunar phases in March



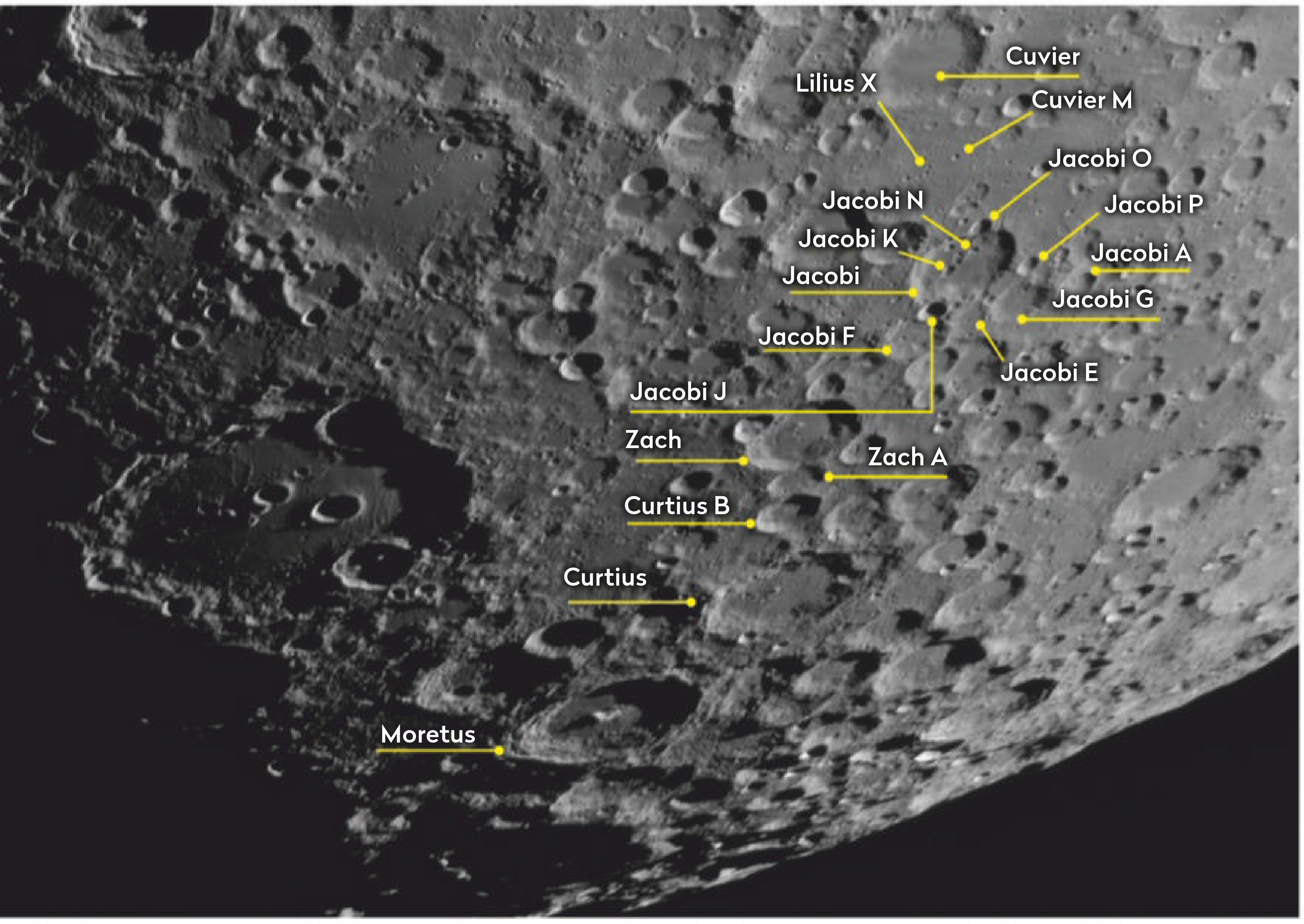
MORE ONLINE

Paul and Pete's night-sky highlights

Southern Hemisphere sky guide

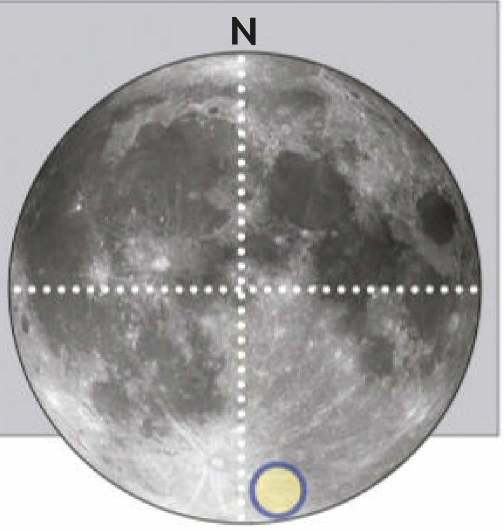
MOONWATCH

March's top lunar feature to observe



Jacobi

Type: Crater
Size: 68km
Longitude/latitude: 11.3˚ E, 56.8˚ S
Age: Older than 3.9 billion years
Best time to see: Six days after new Moon (1 & 30 March) and five days after full Moon (15–16 March)
Minimum equipment: 50mm refractor



Crater **Jacobi** is located in the southern highland region of the Moon and this in itself creates something of a challenge when trying to locate it. There are lots of craters in this region which look quite similar. If you're a newcomer to lunar observing or just not that familiar with this region of the Moon, locating craters like Jacobi is a great way to learn.

One way to find it is to use a similar technique to star-hopping. On the Moon's surface it's the craters that provide the navigational guides but there is a twist. The Moon's appearance is constantly changing as seen from Earth. Its phases and libration – the small rocking and rolling action that occurs due to the Moon's orbital characteristics – means navigational markers may or may not be visible. Some features also appear to change shape slightly due to libration.

So, how do you find crater Jacobi? Probably the best guide is 114km **Moretus**, which is located 475km to the south. Moretus is straightforward to identify because it's large and has well-defined terraced walls leading to a flat floor. Its defining characteristic is a central mountain which appears to cast a dramatic pointed shadow across the crater's floor; a bit like the hand on a giant lunar clock. From Moretus, head north and slightly east to locate 96km **Curtius**. Centre-to-centre, Moretus to Curtius are 150km apart. Curtius looks like a battered version of Moretus with no central mountain.

Immediately north of Curtius are two similar-sized craters, 41km **Curtius B** and 36km **Zach A**. These lead the way to 71km **Zach**. Now head northeast by approximately two times Zach's diameter and you'll arrive at **Jacobi**. Before you arrive, be sure to check out the distinctive line of west-east craters **Jacobi F** (42km), **E** (23km), **G** (42km) and **A** (28km), south of **Jacobi**.

Jacobi is an old crater which looks like a gentle circular depression on the lunar surface. An equatorial triangle of smaller craters overlays Jacobi; 17km **Jacobi O** cutting into Jacobi's northern rim, 19km **Jacobi J** cuts into the southern rim with 15km **Jacobi P** sitting just outside Jacobi's southeast rim.

Jacobi's floor is relatively flat but disturbed by smaller craters. Of particular interest is the chain of craterlets starting at 9km **Jacobi K** in the southwest, extending through 8km **Jacobi N** in the northeast. These point to a small channel in Jacobi's northeast rim, just east of Jacobi O. This channel is formed from four 3km, overlapping craterlets around 3.5km in depth.

> *Jacobi is an old crater which looks like a gentle depression on the lunar surface*

Like much of the southern highlands, the flat areas between craters are pock-marked with tiny craterlets. A great example of this surface type can be seen to the north of Jacobi, between it and the 75km crater **Cuvier**. Such a spread of craterlet sizes is a great test for high-resolution imaging setups. Starting from relatively large examples such as 6km **Cuvier M**, see whether you can record 4km **Lilius X** and craterlets below this size. High-end amateur equipment should be able to resolve down to 700m under stable conditions and there are plenty of craterlets in between the 4km to 0.7km range to test your skills on here.

PETE LAWRENCE X 5

COMETS AND ASTEROIDS

Asteroid 27 Euterpe reaches opposition on 14 March in the constellation of Virgo

Asteroid 27 Euterpe reaches opposition on 14 March when it will appear as a mag. +9.4 object in Virgo, located close to the Virgo-Leo border and just west of the large asterism known as the Bowl of Virgo. During March the asteroid's track begins within the bowl just to the north of mag. +3.6 Zavijava (Beta (β) Virginis). By the month's end, Euterpe crosses the border into Leo, ending up close to mag. +4.0 Sigma (σ) Leonis.

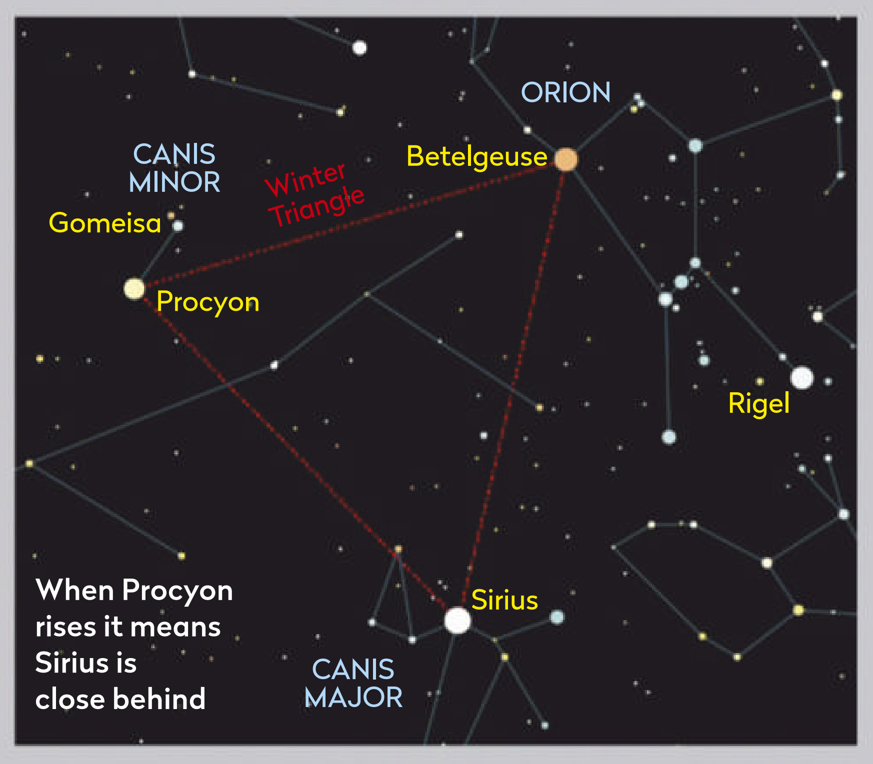
Reaching mag. +9.4 at opposition puts Euterpe around a magnitude fainter than the best it can achieve at a perihelic opposition – an opposition which occurs when the asteroid is at the closest point in its orbit to the Sun. Its elliptical orbit takes it out as far as 2.75 AU from the Sun and in as close as 1.94 AU. An orbit for Euterpe takes 3.59 years to complete. The body's spin has been determined from accurate light curve measurements to be 10.4 hours.

27 Euterpe is a stony object measuring almost 100km across. A two-dimensional profile dimension of 124x75km was determined from an occultation observation. Its orbit lies within a region of the asteroid belt known as the inner asteroid belt. There are various ways of subdividing the asteroid belt but one convenient method uses natural resonance gaps within the orbits known as Kirkwood gaps to provide definition. The inner main belt describes bodies whose orbits mostly lie closer to Mars out to 2.5 AU. This asteroid is the parent body of a group of asteroids known as the Euterpe family, all of the 400 or so members of this family being stony asteroids like Euterpe.

As March begins, Euterpe shines at mag. +9.7, making it ideal for small scope views. It brightens for opposition and then fades back to mag. +9.9 on the 31st when it lies 1.6° to the east-northeast of Sigma Leonis.

STAR OF THE MONTH

Procyon, Canis Minor's bright beacon



Procyon (Alpha (α) Canis Minoris) is the brightest star in Canis Minor, shining at mag. +0.4. On charts the constellation is depicted as a single line connecting Procyon to mag. +2.9 Gomeisa.

Having no bright stars nearby, Procyon stands out in the winter and early spring night sky. It is a vertice of the Winter Triangle, a large asterism formed with Sirius (Alpha (α) Canis Majoris) and Betelgeuse (Alpha (α) Orionis). Although not directly connected, Procyon does share some physical attributes with Sirius.

Like Sirius, Procyon is a neighbour to the Sun. Sirius lies 8.6 lightyears away, Procyon 11.5 lightyears. Sirius has a spectral class of A0 (white), Procyon F5 (yellow-white). Sirius is the brightest night time star, Procyon the eighth brightest. Both have white dwarf companions. The one around Sirius is nicknamed the Pup and at mag. +8.5 is tricky to see or image due to Sirius's glare.

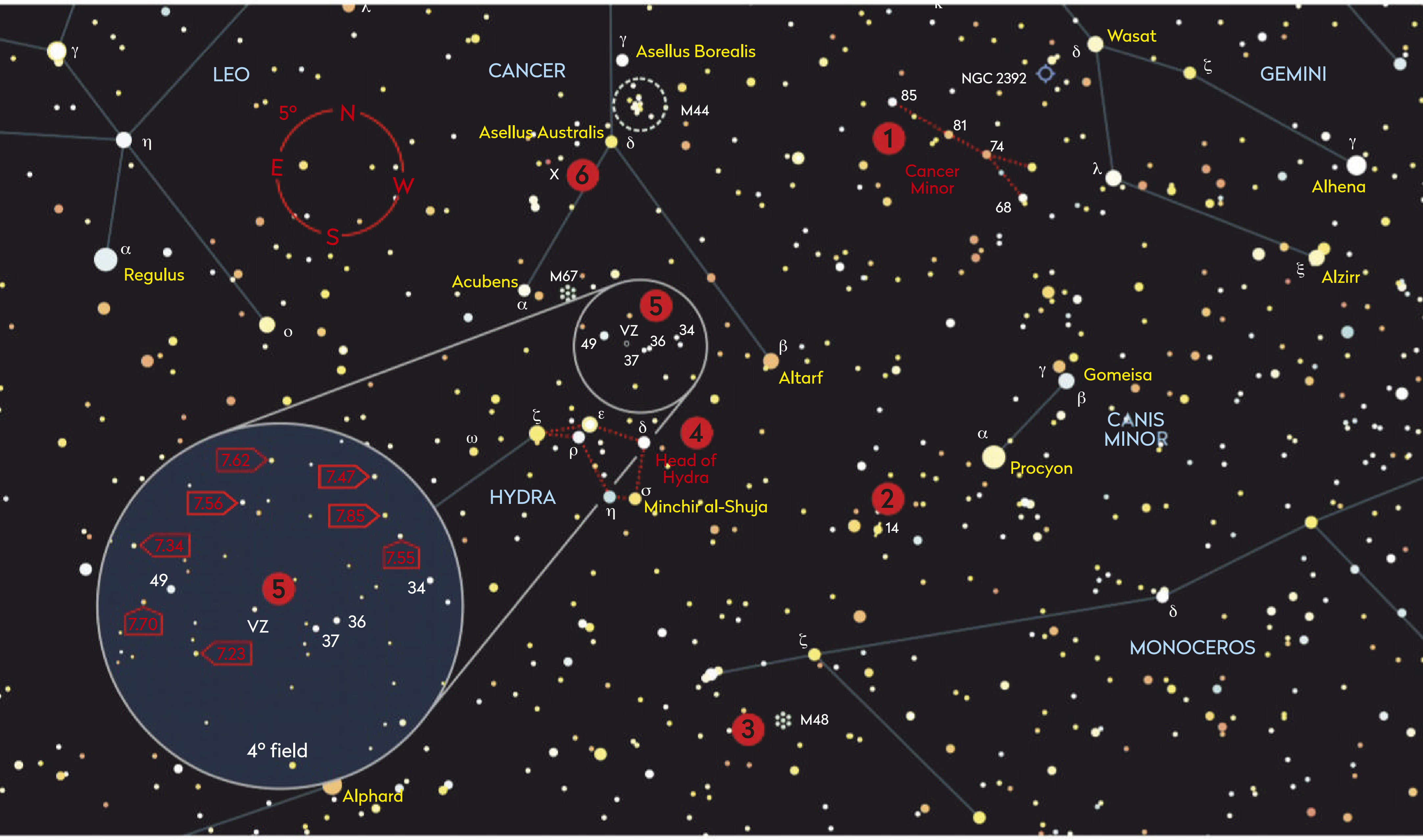
Procyon A (the primary) has Procyon B (white dwarf) with a mutual orbit of 40.8 years (Sirius A and B orbit one another every 50 years). Procyon B is faint however, at mag. +10.8; fainter than Procyon A by a factor of 15,000. The average orbital distance is 15 AU but this is an eccentric orbit which takes the stars from 8.9 AU at their closest, out to 21 AU at their furthest.

Procyon's full spectral classification is F5IV-V, a late stage main sequence star. It has a mass 1.5 times that of the Sun and is evolving into a sub-giant. It is expected to swell into a red-giant star over the next 80-150 million years. Ultimately, its outer layers will form a planetary nebula, with Procyon A also ending up as a white dwarf.

The name Procyon means 'before the dog' a reference to the fact that its rising was an indication that the Dog Star, Sirius, would be rising soon.

BINOCULAR TOUR With Steve Tonkin

Cancer, Hydra and Monoceros point the way to the best binocular highlights in March



1. Cancer Minor

10x 50 The 16th-century Flemish astronomer Petrus Plancius defined many constellations that still survive, but his Cancer Minor, the Little Crab, lasted only a few decades. This may be because it appears like a longer and fainter version of the constellation Sagitta, and almost nothing like the crab it represents. Still, it is a pretty asterism of coloured 5th magnitude stars that extends nearly 7° from 85 Geminorum to 68 Geminorum. ☐ **SEEN IT**

2. 14 Canis Minoris

15x 70 Canis Minor may not top lists of interesting constellations, but it does have one treat for binocular astronomers. 5.5° southeast of Procyon (Alpha (α) Canis Minoris) you will see a pair of orange stars. The fainter, westernmost one is 14 Canis Minoris, an easily splittable triple star, with its mag +9.3 and +9.7 comites (companions) lying 101 and 136 arcseconds away to the east and southeast respectively. ☐ **SEEN IT**

3. The Missing Messier

10x 50 Charles Messier incorrectly catalogued the position of M48, but it was more than 150 years after Caroline Herschel re-discovered it in 1783 that astronomers realised she'd found the object matching Messier's description. This open cluster lies 3° southeast of Zeta (ζ) Monocerotis, appearing as a condensed patch of stars. With 10x50 binoculars, you can resolve a few brighter stars against the background of fainter stars. ☐ **SEEN IT**

4. The Hydra's Head

10x 50 The head of this nemesis of Heracles is defined by six stars between magnitudes +3.1 and +4.4, but curiously only the faintest of the six, Sigma (σ) Hydrae, retains a common name, Minkhir al-Shuja (hydra's nostril), that relates to the Hydra in Greek mythology. Binoculars of any size enable you to enjoy the wide variation in colours, from the intense white of Eta (η) to the yellow-orange of Zeta (ζ). ☐ **SEEN IT**

5. VZ Cancri

15x 70 If you'd like to watch a star complete its cycle of variability in a single session, this is the one for you. VZ Cancri varies between mag. +7.2 and +7.9 over a period of 4 hours 17 minutes. You'll find it midway between 49 and 36 Cancri. VZ is an RR Lyrae variable; it has a steep rise in brightness followed by a gradual dimming. The inset chart shows the magnitudes of some comparison stars. ☐ **SEEN IT**

6. X Cancri

10x 50 Just over 2° east of Delta (δ) Cancri is a 1° line of three 6th and 7th magnitude stars. The middle one is X Cancri. This red star is a semiregular variable carbon star which has a main period of 180 days and a magnitude range of +5.7 to +6.9. Semiregular variables are giants or supergiants whose main period is overlain by irregular changes in magnitude. ☐ **SEEN IT**

☑ Tick the box when you've seen each one

PETE LAWRENCE X 3

THE SKY GUIDE CHALLENGE

Look out for earthshine, where light reflected off Earth lights up the Moon's dark side

Also known as the Da Vinci Glow, earthshine allows us to see features on the Moon's dark side

Another, more poetic term for the effect of earthshine is 'the old man in the young Moon's arms'

Earthshine is a phenomenon which allows us to see the dark, night side of the Moon. This month we're challenging you to reveal this beautiful effect, assess how long it's visible for and to observe features faintly lit by this dim reflected light from Earth.

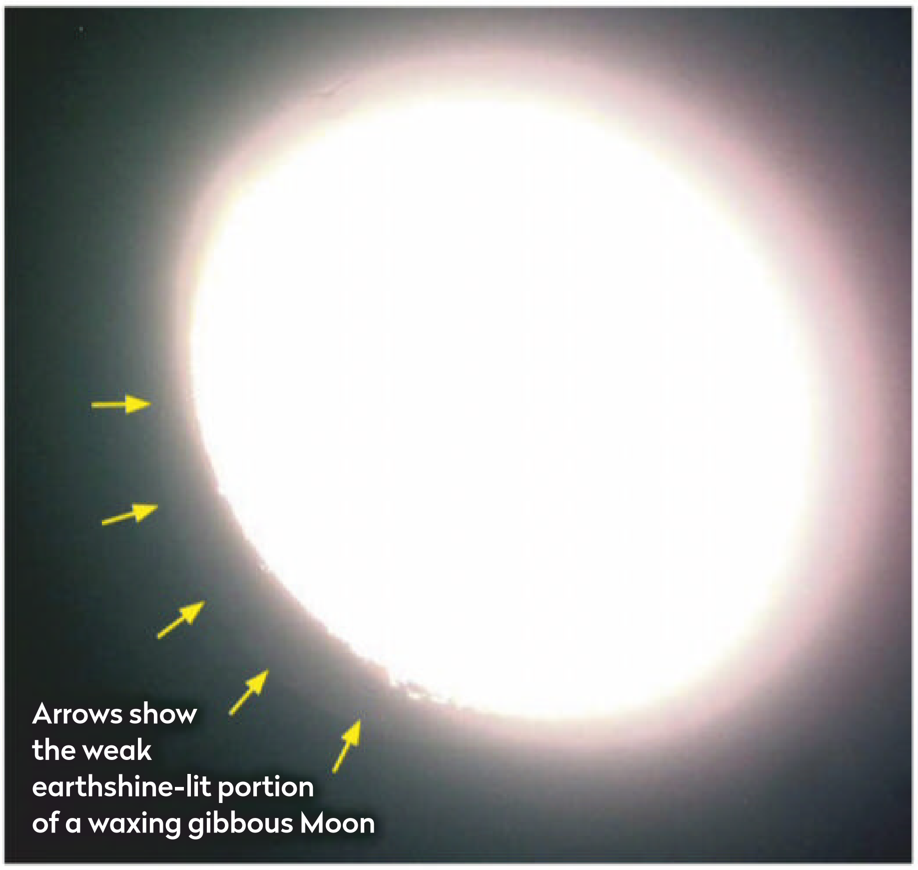
To understand the effect, it's important to be able to imagine what Earth looks like from the Moon. Our planet is more reflective than the Moon by quite some margin. Although you might not think it, the Moon's reflectivity is about the same as an asphalt road. Earth is also approximately four times larger than the Moon. Put together it's not hard to imagine that Earth would appear big and bright as seen from the lunar surface.

What about the phase of Earth? We're all familiar with the phases of the Moon caused by the varying Moon-Earth-Sun angle as our neighbour travels around its orbit, but what would Earth look like from the Moon? It too would go through a complete set of phases but these will be the complementary ones to what we see from Earth. When the Moon is full in our sky, Earth will be new in the Moon's sky. When the Moon is a thin crescent, Earth would appear with a large gibbous phase.

The thin crescents we see just before and after new Moon therefore represent times when Earth's light shining onto the Moon is at its strongest. This light illuminates the dark, night portion of the Moon's Earth-facing side and reflects back to Earth, allowing us to see the lunar night hemisphere glowing gently. This is what's known as earthshine. Another, more poetic term for the effect is 'the old Moon in the young Moon's arms', describing the appearance we get with the early evening crescent Moon when it reappears just after the new phase.

Looking at the earthshine-lit portion of the lunar disc with a scope it is just possible to see certain features. The most obvious is the bright crater Aristarchus near to the western limb.

Photography is another excellent way to reveal features within the lunar night. Deliberately over-exposing a bright lunar crescent will reveal many details from the 'dark side', rendering the night portion as detailed as it appears when properly lit. And here lies yet another challenge. It's pretty easy to see and photograph the earthshine-lit portion of the Moon when the Moon is showing as a thin crescent, but how close to full Moon can you get and still record the effect. Give it a go, you might be surprised. Given clear skies, look for earthshine from 26 March.



Arrows show the weak earthshine-lit portion of a waxing gibbous Moon

DEEP-SKY TOUR

We locate the galaxies and nebulae that fill the sky around Ursa Major

1 M108

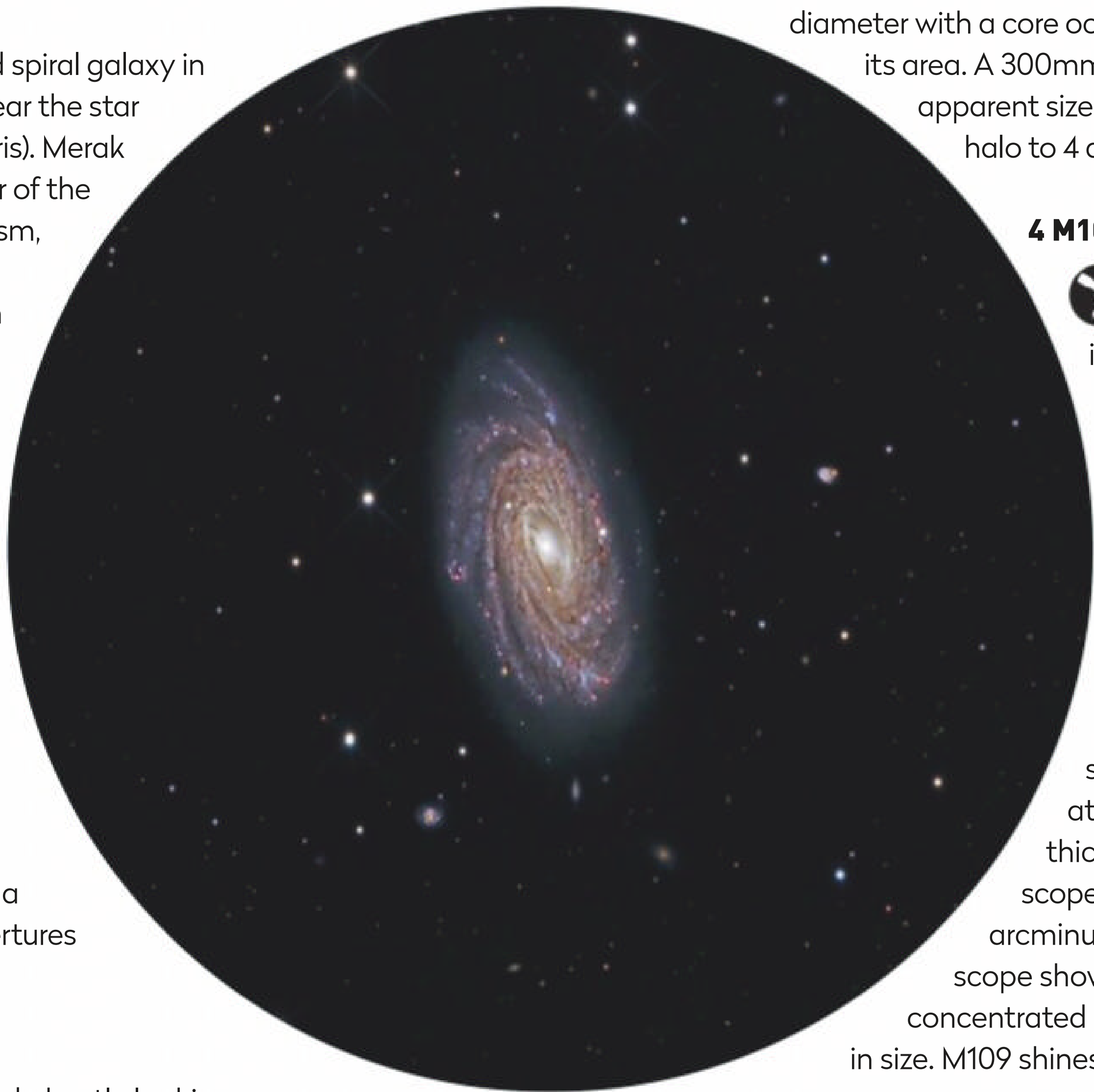
Messier 108 is a barred spiral galaxy in Ursa Major, located near the star Merak (Beta (β) Ursae Majoris). Merak marks the southwest corner of the pan of the Saucepan asterism, also known as the Plough. Locate the galaxy one-fifth of the way along the bottom of the pan from Merak towards Phecda (Gamma (γ) Ursae Majoris), the galaxy lying 19.7 arcmintes south of this position. A 150mm scope shows an elongated object 8 arcminutes in length and less than 1.5 arcminutes wide. Increasing power reveals that this elongated glow is not uniform but has a mottled texture. Larger apertures show this well. ☐ **SEEN IT**

2 M97

M97 is a large and ghostly looking planetary nebula located 0.8° southeast of M108. Through a small scope it looks like a fairly even circular glow. A 250mm scope shows two dark patches, the whole affair resembling the face of an owl, hence M97 is known as the Owl Nebula. A 300mm scope at 150–200x power shows the 'eyes' well. Each eye appears around 50 arcseconds across. M97 shines with an integrated magnitude of +9.9 and has an apparent diameter around 3 arcminutes, which gives it a low surface brightness. The dark eyes represent the openings of a tube-like nebula aligned so we see both openings within the nebula's border. M97 lies at a distance of 2,300 lightyears. ☐ **SEEN IT**

3 NGC 3631

Next, we visit NGC 3631 a face-on spiral galaxy with an apparent magnitude of +10.1. It's located 2° south-southeast of M97, around 2.3° south of the centre of the line which forms the bottom of the Saucepan's pan. Although it has a reasonable magnitude for a galaxy, the fact that it appears face-on delivers an object with low surface brightness. A 250mm scope shows a glow around 2 arcminutes in diameter with a core occupying one-quarter of its area. A 300mm scope increases the apparent size of the galaxy's outer halo to 4 arcminutes. ☐ **SEEN IT**



▲ **Barred spiral galaxy NGC 3953 is around 50 million lightyears from Earth**

4 M109

M109 is easy to locate. Extend the imaginary line from Merak through Phecda for 39 arcminutes (one-twelfth the length of the Merak-Phecda line). M108 is a good comparison for M109, the latter appearing a bit dimmer and smaller. Like M108, M109 is a barred spiral galaxy, but here tilted at a wider angle, giving it a thicker appearance. A 150mm scope shows an oval glow 3x5 arcminutes in size, while a 250mm scope shows a faint halo with a concentrated core, 1.5x1 arcminutes in size. M109 shines at mag. +10.6. ☐ **SEEN IT**

5 NGC 3953

Another barred spiral galaxy, NGC 3953, is located 1.4° south of Phecda and shines at mag. +10.1. This galaxy has a brighter appearance than M109 due to it being presented at a reasonable tilt angle which maintains surface brightness. It also has an inner ring structure that circles its barred core. It appears 5x2 arcminutes in size through a 150mm scope, increasing in width marginally as you up the aperture. At high powers through a 300mm instrument, the appearance of the galaxy becomes less homogenous and more granular thanks to tightly wound spiral arms that surround the core. ☐ **SEEN IT**

6 NGC 4088

Our final stop is NGC 4088, an intermediate spiral galaxy located 3.6° south-southeast of Phecda, 2.7° southeast of NGC 3953. The other galaxies visited so far have all had linear elongations in the shape of their cores; the bars which give them their 'barred' classification. An intermediate spiral galaxy is a type which sits between a barred and an unbarred type. NGC 4088 shines at mag. +10.5 and is easy to see through a 250mm scope with an apparent size of 5.5x3 arcminutes. A 300mm scope shows that the core shape is not regular, appearing to thin quite abruptly. At higher powers NGC 4088 appears quite mottled in appearance. The mag. +12.3 edge-on galaxy NGC 4085 lies 11 arcminutes to the south. NGC 4088 is estimated to be 52 million lightyears away. ☐ **SEEN IT**

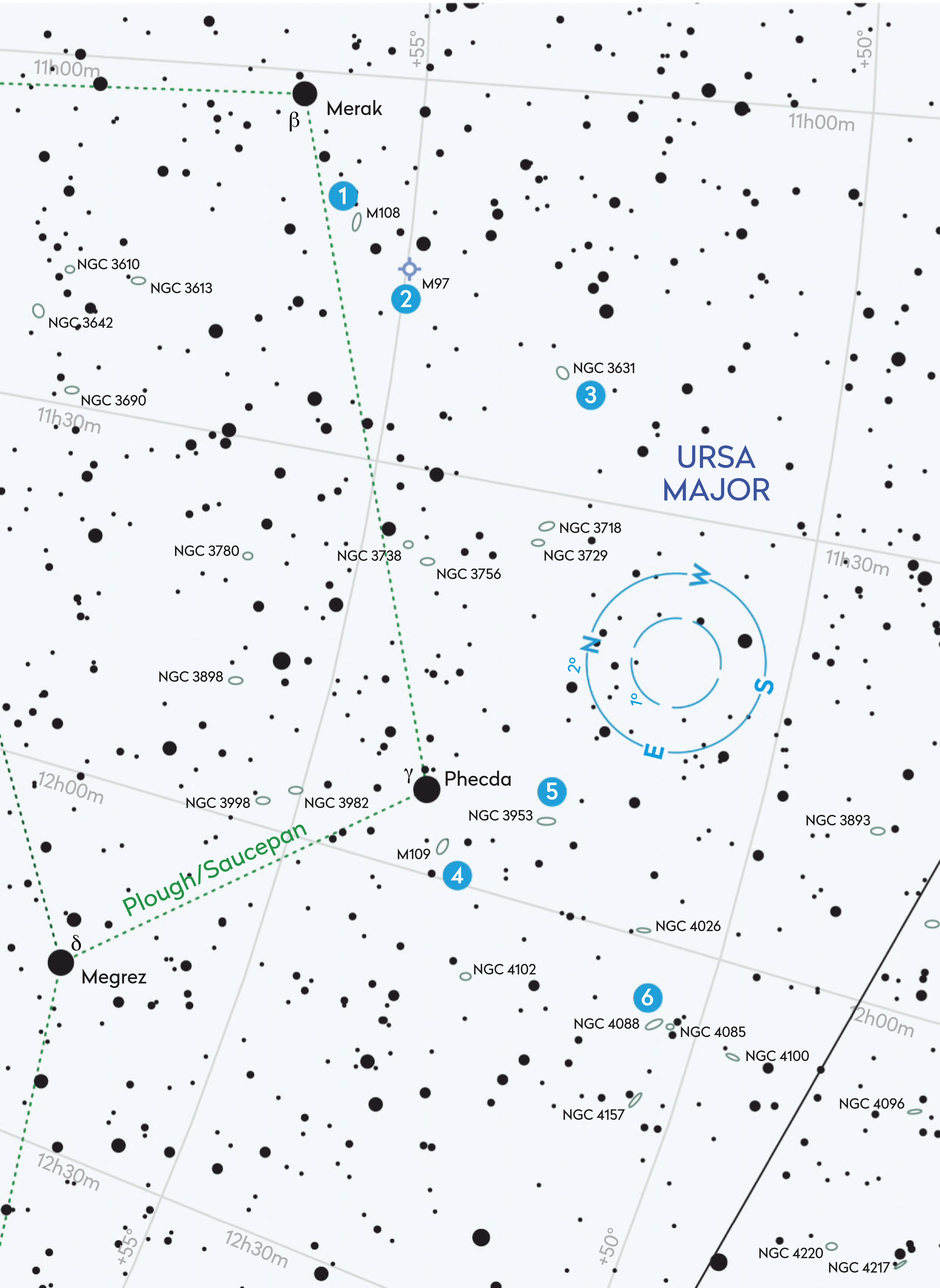
This Deep-Sky Tour has been automated

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

More **ONLINE**

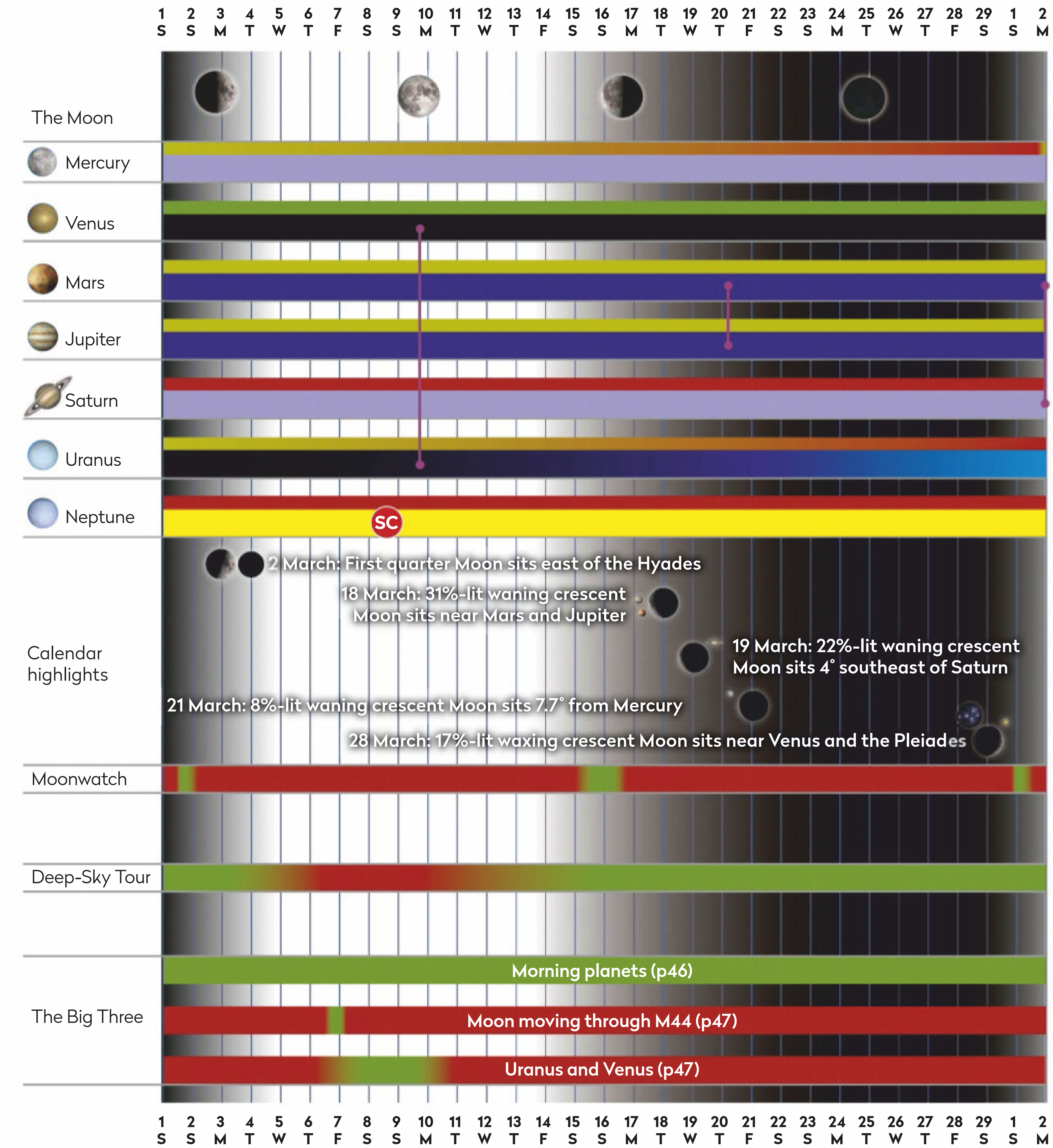
Print out this chart and take an automated Go-To tour. See page 5 for instructions.

MARTIN RUSTERHOLZ/CCDGUIDE.COM, CHART BY PETE LAWRENCE



11h00m
+55°
+50°
Merak
β
11h00m
1
M108
NGC 3610
NGC 3613
M97
2
NGC 3642
NGC 3631
3
NGC 3690
11h30m
URSA
MAJOR
NGC 3718
NGC 3780
NGC 3738
NGC 3729
NGC 3756
11h30m
W
N
2°
1°
S
E
NGC 3898
γ
Phecda
5
12h00m
NGC 3998
NGC 3982
NGC 3953
NGC 3893
Plough/Saucepan
M109
4
δ
NGC 4026
Megrez
NGC 4102
6
12h00m
NGC 4088
NGC 4085
NGC 4100
NGC 4157
NGC 4096
12h30m
12h30m
+55°
+50°
NGC 4220
NGC 4217

AT A GLANCE How the Sky Guide events will appear in March



KEY

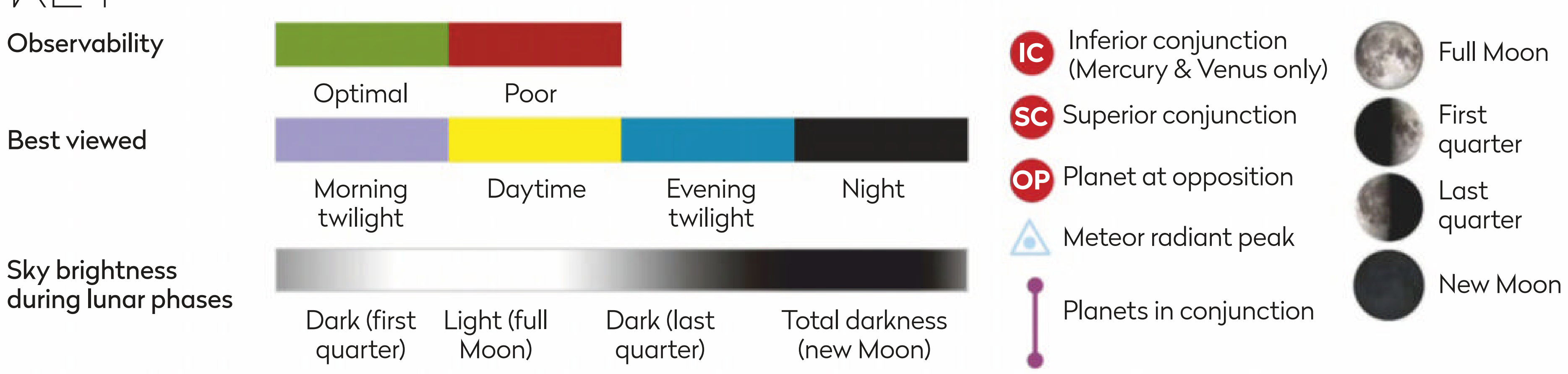


CHART BY PETE LAWRENCE

Dark materials: the Taurus Molecular Cloud, containing the dark nebula Barnard 22, is made from interstellar dust and gas

Delight in the DARKNESS

Will Gater delves into the world of dark nebulae to show you how to image and explore these hidden celestial gems

WILL GATER

For those of you seeking something a little different in 2020, this year could be the perfect time to turn your attention to the objects hiding in the shadows: dark nebulae. The night sky abounds with these shadowy wisps and their tendrils of dim nebulosity. They make tremendously rewarding imaging subjects. If you have dark skies and a little patience some can even be tracked down at the eyepiece too.

Dark nebulae are where most of the stars in the night sky begin their life, since it is in the cold recesses of these vast clouds that they are born. Indeed, the dazzling star-forming regions that pepper the night sky would all have been gloomy dark nebulae at one point.

The disc of our Galaxy is full of these filigree phantoms. We see this most prominently in the 'dust lanes' that weave through the Milky Way. There are many more examples to be found away from these main lanes however, especially if you're equipped with a camera.

As they do not emit visible light, dark nebulae are primarily visible when they sit in front of a backdrop of rich star fields; that's one reason why they're such inviting subjects for astrophotography. In some cases – as with the iconic Horsehead Nebula – they appear starkly contrasted against swathes of bright emission nebulae.

For astrophotographers, dark nebulae offer the chance to image an interesting or unusual deep-sky feature in what, to the casual observer glancing across a star chart, might look like a completely empty patch of sky, albeit one flecked with stars.

Some of the most spectacular dark nebulae images also show how these objects often hide, concealed in darkness near to other brighter targets. Examples of where this occurs in the winter sky include the magnificent Taurus Molecular Cloud near the Hyades and Pleiades star clusters, and the complex of dark nebulae to the northwest of the Christmas Tree Cluster, NGC 2264. In summer, the dark nebulae-littered regions that border the main Milky Way dust lanes in Sagittarius, Scutum and Serpens offer similarly rich pickings for imagers using wide-field lenses or telescopes and sensitive cameras.

Deep-sky thinking

Even if brighter targets aren't included in an image, chasing the faint details of isolated dark nebulae can provide a route into original and innovative compositions if you're an experienced deep-sky imager after a new angle for your work. And, at least in this astrophotographer's opinion, these objects also often give the most striking impressions of depth in astro images – perhaps due to them frequently being set in front of almost granular curtains of myriad distant stars.

Because they are intrinsically faint, dark nebulae can be quite technically challenging to image – even for astrophotographers familiar with deep-sky imaging and processing. If you're using a telescope or longer focal length camera lens as your main optics you'll typically need to capture a large number of ▸

▲ A shot in the dark: point towards the Christmas Tree Cluster in the winter sky to find nearby dark nebulae. The pretty Rosette Nebula is on the left

ALL PICTURES: WILL GATER

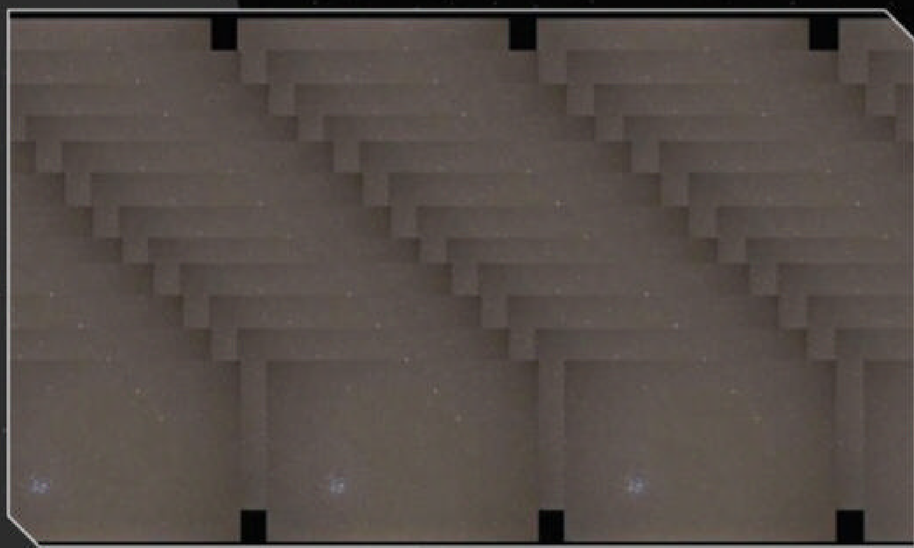
Imaging dark nebulae – the basics

A step by step guide to basic dark nebulae photography with a prime lens and DSLR or mirrorless camera

Fast, prime (ie not zoom), camera lenses used with a DSLR or mirrorless camera on a tracking mount offer a basic but highly effective way of shooting wide-field images of dark nebulae. Some lens models produce particularly sharp images and this, coupled with often tremendous light-gathering power at full aperture, means detailed pictures can be achieved in a relatively short amount of time. Here we look at the main steps you'll need to get the shot.

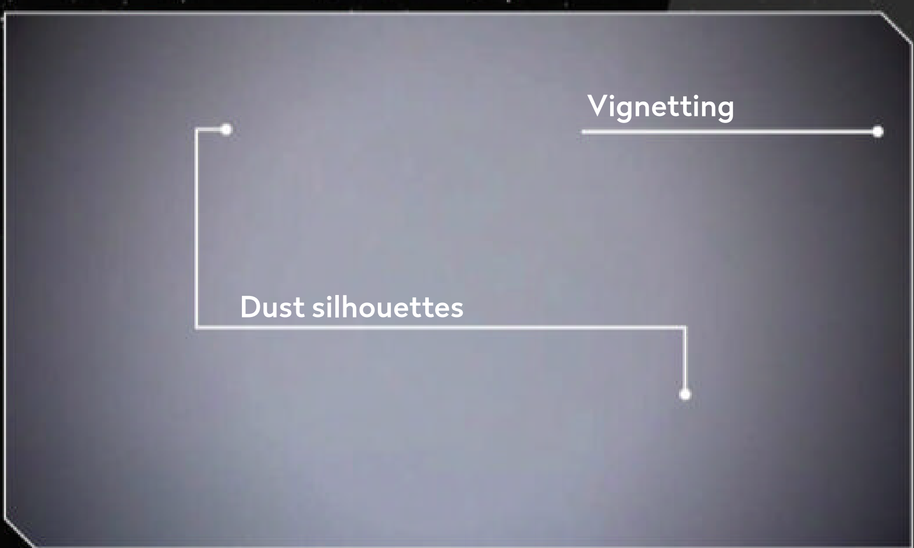
Initial set up and aperture testing

Once your tracking mount and camera are set up, take a little time to set the aperture of your lens. By stopping down the lens slightly you may be able to achieve tighter star shapes and lessen vignetting. We'll capture a flat field later to tackle this, but anything you can do at this stage to reduce such aberrations and even out the illumination will help when you eventually try to pull out the faint detail of the dark nebula later in processing. At this stage, note the configuration of the lens so it can be replicated exactly when we make the flat field.



Gather the data

Because dark nebulae are so faint we need to push the exposure lengths. How long you go is a balance between fogging the frame with light pollution and how much noise (unwanted artefacts) you're happy with on one hand and the detail you're picking up on the other. Experiment with ISO and exposure lengths. With that sorted, take as many exposures as you can. Get rid of those showing haze or cloud, even if it's subtle. It can be easier to sift through these by flicking through the images on the rear camera screen, as gradients can show up more clearly there than on a large computer monitor.

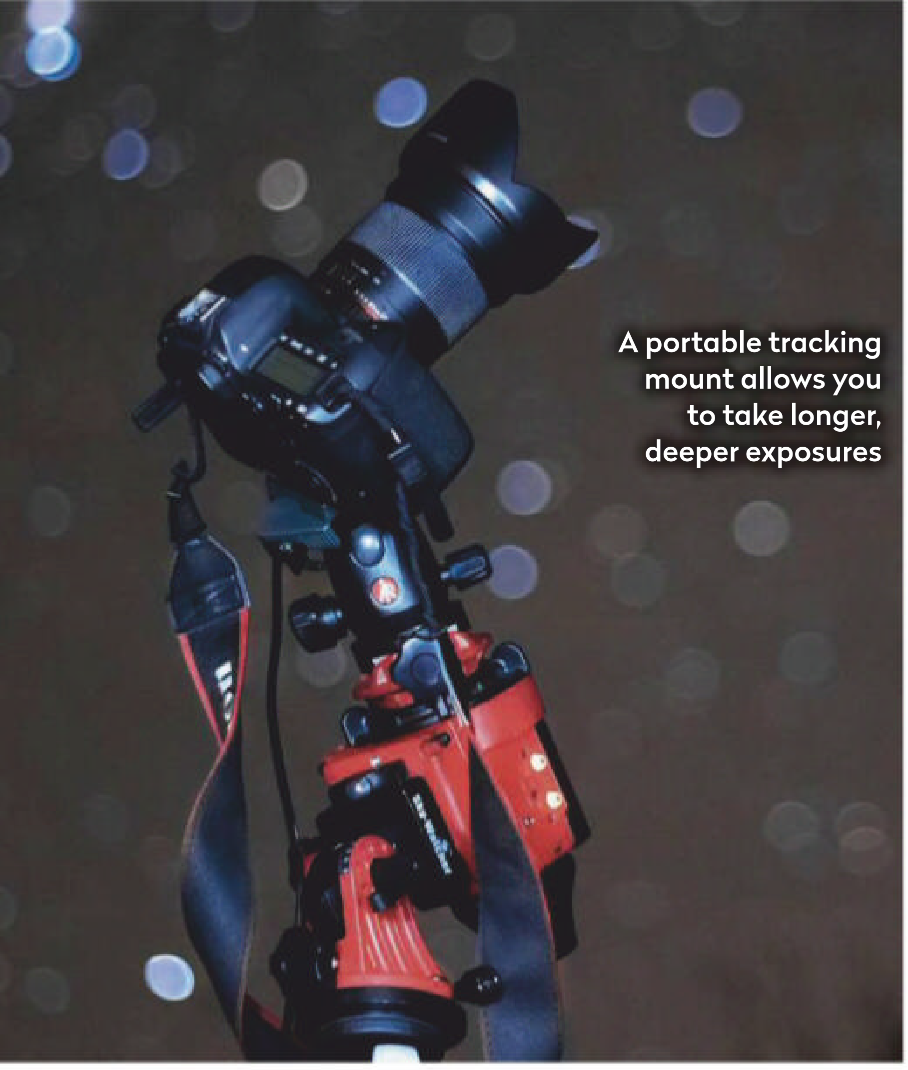


Flat fielding and stacking

Next we need to create a flat field image. When using a camera lens you can capture very basic flat fields simply by replicating the original shooting configuration (focus point, lens aperture) and then pointing the camera at a bare patch of a smooth, white internal wall that's evenly lit. Set your DSLR to auto-expose the image and take around 10 to 15 images. These images can then be used in stacking software to create a 'master' flat field for the main image data. Finally, stack the exposures you have and calibrate them with this master flat field.

Stretching the data

We now need to 'stretch' the stacked image to pull out faint features. One simple way to do this is to use the 'curves' tool found in many image editors. Bend the diagonal line of the curves tool so it takes on an 's' shape; pull up the right side of the line to brighten the image and if necessary pull down the lower left part of the line, slightly, to increase contrast. Apply the adjustment and repeat to taste. You should gradually see faint details appearing. From here you can make the usual image-editor tweaks such as colour balancing and noise reduction.



A portable tracking mount allows you to take longer, deeper exposures

▸ high-quality long exposures in order to reveal the nebula clearly against the inherently dark background of space. One consequence of this is that, for anything other than a simple wide-field shot, a good motorised tracking mount is an essential requirement.

Image data showing dark nebulae often needs more attention at the processing stage, as a lot of the structure of these objects sits in the darker portions of the picture. When these regions are enhanced, image defects such as strong vignetting (corner darkening) or the dark, blobby silhouettes left by dust in the optics show up very clearly. Taking a basic flat-field calibration file – which can remove these defects – is therefore a crucial step for most telescopic and long-camera-lens imaging of dark nebulae.

Another challenge is that, while decent pictures of most deep-sky targets can be captured on nights of less-than-ideal transparency, dark nebulae images are particularly susceptible to degradation by haze and very thin cloud. This can reduce the contrast in the final processed image, making it harder to pick out the subtle nebulosity. It can also be a source of distracting gradients caused by scattered light pollution, which mask details in the faint shadows of a picture. The good news is that there are numerous dark nebulae on show during the winter months in the Northern Hemisphere, when clear nights can often mean crisp, transparent skies.

Find your own level

All this being said, there are entry points into photographing these beautiful objects for every level of astrophotographer, as well as targets suitable for imaging under moderately light-polluted suburban skies. Good examples of dark nebulae that are within reach of a basic DSLR, kit lens and static photo tripod are the Milky Way's main dust lanes visible in the summer and autumn, and larger features such as the Pipe Nebula; these can be picked up with even 30-second exposures and mid-to-high ISO settings.

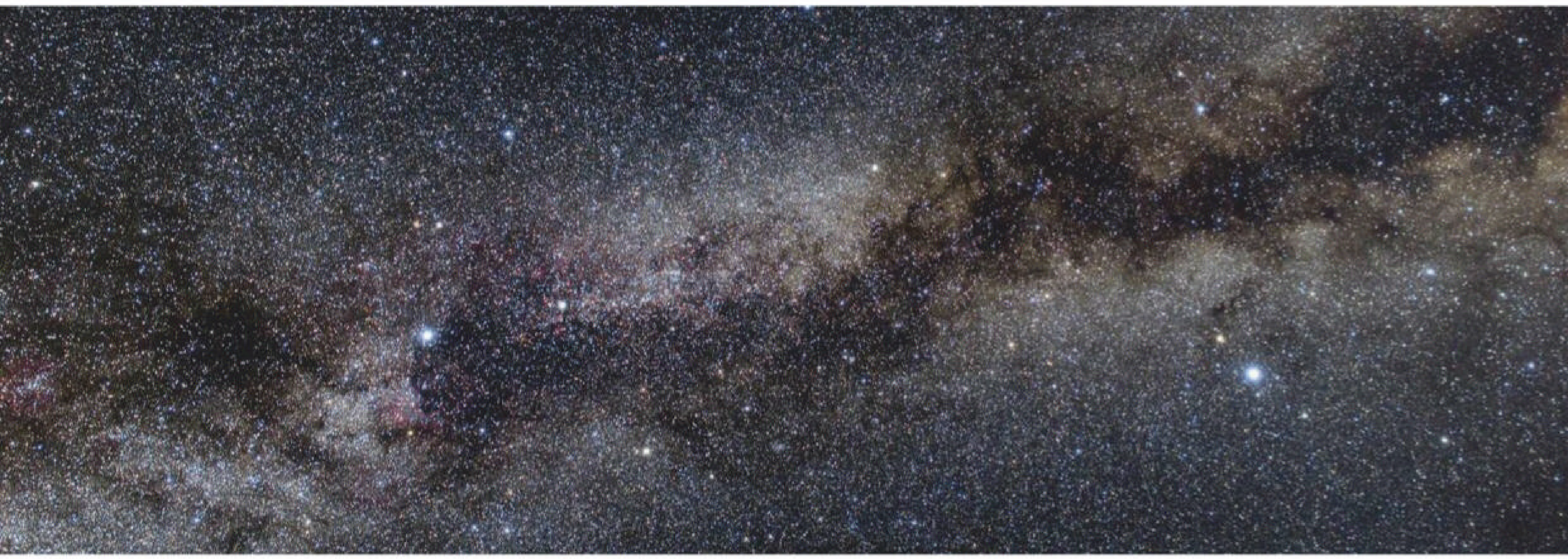
For imagers looking for more testing targets, finding dark nebulae to shoot can be a challenge in itself. Of course you can always look online and see what other astrophotographers are imaging, but if you want to go off the beaten track and see what else is out there it's best to fire up a planetarium program. Most good software – such as Stellarium, SkySafari and Cartes du Ciel – will list catalogues and locations for dark nebulae. The free Stellarium, for example, can show the positions of nebulae in the Barnard and Lynds catalogues of dark nebulae, and includes a function where you can overlay the image data from different surveys on the plotted sky. For example, the 'Planck R2 HFI colour composition' layer can be used to trace the locations of dark nebulae.

With this information in hand and plenty of potential subjects up there, there's no reason to keep yourself in the dark about the wonders of these dim and distant delights.

Will Gater is an astronomy journalist and science presenter based in the UK

ALL PICTURES: WILL GATER

▾ **Finding a target: in the Milky Way's Great Rift you'll see dark 'dust lanes' in the region of the Summer Triangle**



Where to look for dark nebulae

Though tricky to spot, there are a few dark nebulae you can see visually

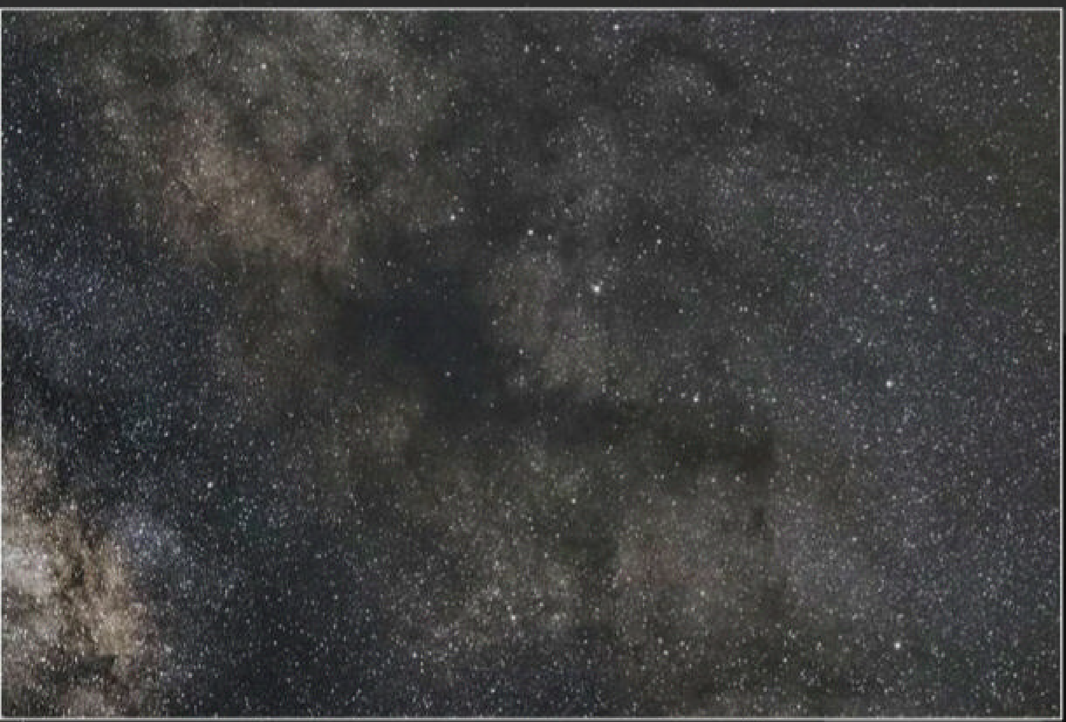
Dark nebulae are among the hardest objects to observe visually in the night sky. Their extremely low brightness makes them almost impossible to discern from light-polluted sites. Here we've picked out a few of our favourites. To give yourself the best chance of seeing them always allow at least 30 to 40 minutes for your eyes to become more dark-adapted before observing. You'll find that observing from a dark-sky site will give you a considerable advantage.

Milky Way dust lanes

Perhaps the easiest dark nebulae to spot are the swathes of silhouetted nebulosity that run through the bright band of the Milky Way. These are known as the Milky Way's 'dust lanes' and are particularly prominent in the summer months when the centre of the Galaxy looms over the southern horizon.

Barnard's E

Just west of the 2nd magnitude star Gamma Aquilae lies a dark nebula that, under dark skies, is a perfect target for a pair of binoculars, or a wide-field eyepiece on a telescope. It's known as Barnard's 'E' due to its resemblance to the letter. Use averted vision (looking slightly away from the object) to pick out more detail.



Pipe Nebula

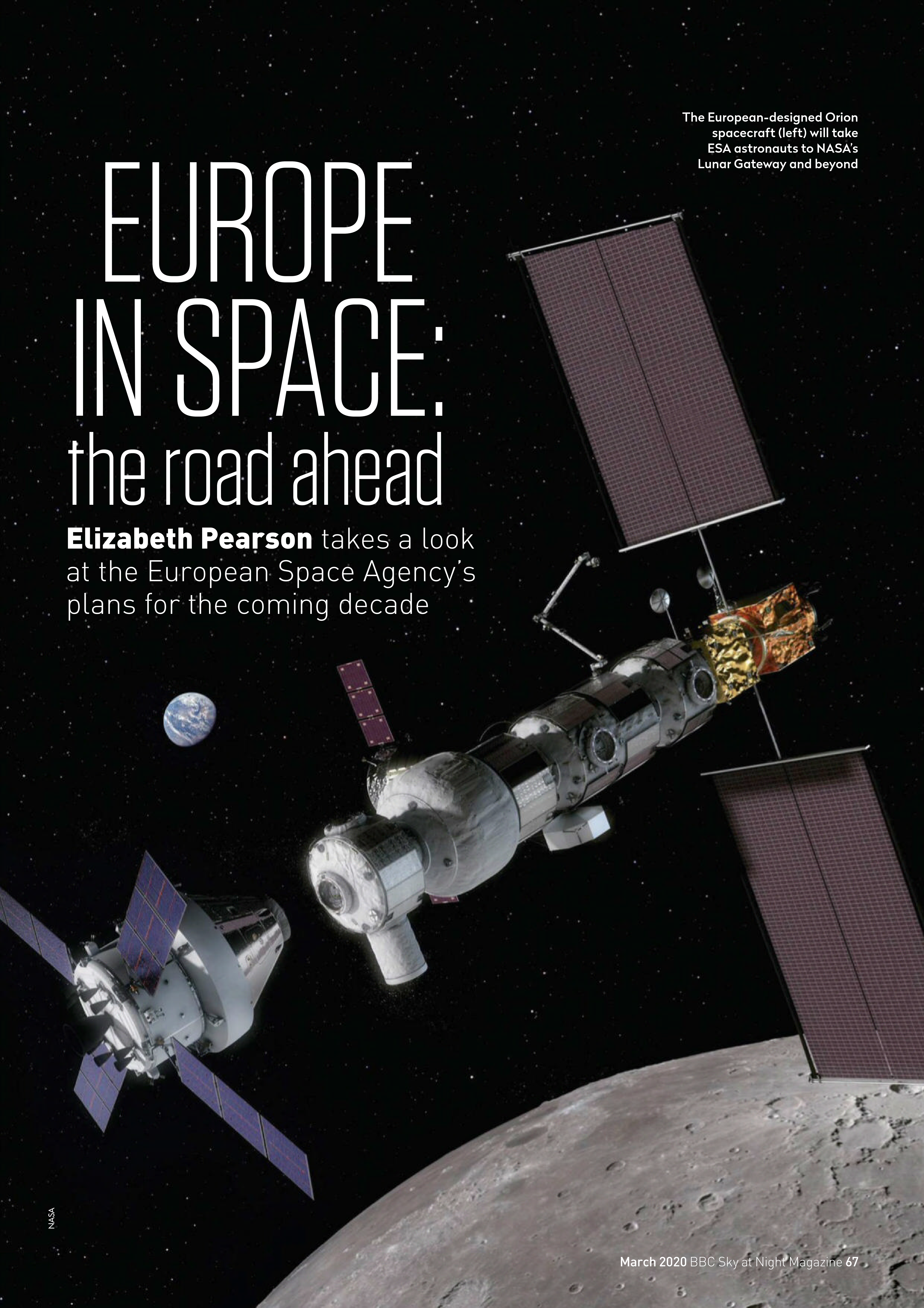
If you have a clear view to the southern horizon during the warm summer months, keep an eye out for this large dark nebula that sits in the very southern corner of Ophiuchus. A good pair of 10x50 binoculars can be used to show it more clearly among the rich star fields in this region.

Horsehead Nebula

The Horsehead is perhaps the most iconic dark nebula in the night sky. It sits close to the bright star Alnitak in the constellation of Orion. A large telescope and dark, transparent skies are needed to see it well. Keep the glare of Alnitak out of the eyepiece field of view if you can, as that will improve your chances.

EUROPE IN SPACE: the road ahead

Elizabeth Pearson takes a look at the European Space Agency's plans for the coming decade



The European-designed Orion spacecraft (left) will take ESA astronauts to NASA's Lunar Gateway and beyond

NASA

▲ **Budget bonanza: ESA's 22 member states approved record levels of funding for future space missions in November 2019**

During late November 2019, science and finance ministers from all over Europe converged on Seville, Spain with one topic in mind – the European Space Agency (ESA). Every three years, the agency hosts one of these ministerial level meeting where government officials from all 22 member nations come together to discuss what direction they believe the agency should be taking and, most importantly, hand over their money.

In this meeting, named Space19+, ESA had some ambitious plans to lay before its member states, and an equally ambitious funding request to make them happen. ESA wanted around €14.5bn over the next three years, its largest increase in 25 years. With several nations exceeding this request – including the UK, which increased its contribution by 15 per cent, bringing its pledge to £374m per year – the agency easily met its target, meaning all its missions were funded.

These meetings are vital as they give ESA the assurance it needs to make long-term plans, knowing that it will be able to afford missions not just now but in the years and decades it takes to achieve them.

One of the biggest is Copernicus, an Earth observation campaign ESA runs alongside the European Union, which took up almost a third of the funding and actually received €400m more than requested.

"Europe, in a combination of Copernicus and other satellites, has a world leadership in Earth observation. The objective is to monitor the Earth system as a whole so that we can contribute information on how to preserve our planet and keep the damage we do to a minimum," says Josef Aschbacher, director of ESA's Earth observation programmes.

The project already has several satellites monitoring our planet but ESA wants to launch six more over the coming decade. These will measure carbon dioxide levels, heat distribution, vegetation coverage, Arctic ice levels and humidity across the globe.

"Europe has a strong climate and green agenda," says Aschbacher. "We're helping politicians to make the best policy decisions to minimise our impact on the planet."

While Europe leads in tackling the climate crisis, there are other areas where

The UK and ESA

Britain is keen to cement its position in the global space market

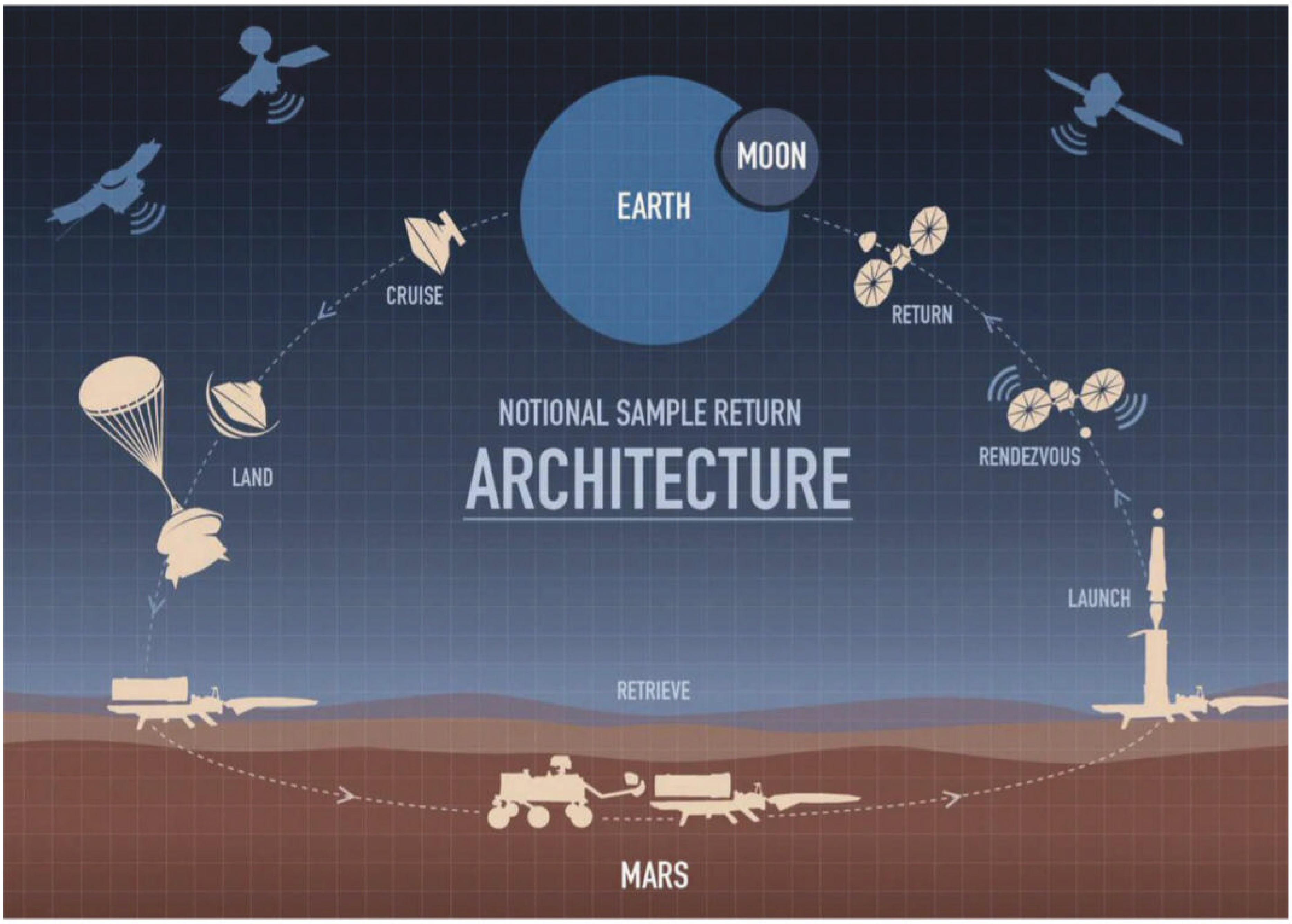
The UK is involved with several key parts of ESA's plans over the next few years.

"A significant piece of UK hardware will go to the ISS next year: a high-speed communications data link which will enable a massive increase in the station's data rate," confirms ESA's David Parker. "The UK is also interested in contributing technologies to the Lunar Gateway, but those competitions are currently ongoing.

"Then on Mars, the UK has particularly expressed a wish to take a lead on the Sample Fetch Rover. There's a strong interest in getting involved in the analysis when the sample comes back as well."

One question that hangs over the UK's involvement in ESA is its place in Europe after leaving the European Union. Though ESA is a separate entity from the EU, there are several projects which the two run jointly, notably the Copernicus initiative.

"The UK has subscribed pretty well to Copernicus and will be participating in a strong manner," says ESA's Josef Aschbacher. "The UK is also a big user of Copernicus data and will remain so. We have a mechanism where the UK will continue with Copernicus until 2021, and then we'll see where it stands with regards to participating in an EU programme."



▲ **An overview of NASA's proposed Mars Sample Return mission. ESA will provide equipment for retrieving cached samples from the Martian surface and returning them to Earth**

it takes a supporting role. When it comes to human spaceflight, ESA cannot compete with the likes of NASA, which spends more on the endeavour in one month than ESA does in a whole year. Instead, ESA works with other nations to get European astronauts into space and the agency is keen to expand this role.

Getting into the Moon's orbit

One key area ESA wants to get involved in is NASA's plan to build the Lunar Gateway, a permanent station in orbit around the Moon. ESA already plays a part in the project by building the service modules for the Orion spacecraft that will take astronauts to the Gateway. However, the agency has a barter agreement with NASA and gives these in exchange for carrying European astronauts to the International Space Station (ISS).

"Up until this ministerial we were just building the hardware and giving it to NASA," says David Parker, director of human and robotic exploration at ESA. "We had no rights to use it. Now we have a plan to build elements of the Lunar Gateway and in exchange we will have the chance to fly ESA astronauts to the Gateway. It's our first step towards deep space exploration."

Europe will create a refuelling hub for the Gateway, where spacecraft bound for either the lunar surface or the return to Earth will be able to replenish their power and propulsion systems. That's due by 2027. ESA will also work with JAXA, the Japanese space agency, to build a module where the astronauts will live, sending it to the Gateway in 2025.

In the meantime, ESA will continue sending astronauts to the ISS, learning how to live and work in space.

"Our plan is to make missions to the ISS with all our astronaut corps, including UK astronaut Tim Peake, by 2024, which is the current nominal end of the station. We fully expect it to continue beyond that date though, so we're investing in modernising the European-built Columbus laboratory," says Parker.

ESA will also be working with NASA on another long-term project: returning samples from the surface of Mars. This July, NASA plans on sending the Mars 2020 rover to the Red Planet to collect rock samples. It will seal these up in tubes that will be left on the surface for a future mission to pick up, which ESA will be a part of.

"We will build a Fetch Rover. This won't have any scientific instruments itself but will have a very sophisticated autonomous navigation and driving facility," says Parker.

The rover will run around the Martian surface collecting the tubes before returning to its base station, where a European-built robot arm will load them into a small rocket. This will then launch its Martian cargo into orbit.

"Having done all that there's an interplanetary pass-the-parcel. The sample container ejects into orbit around Mars, breaking the chain of contamination between the outside of the lander, the rovers and the Mars ascent vehicle. Then we can collect that with a return orbiter which captures the container," says Parker. ▸

TIMELINE

The missions to be launched by ESA in the next 15 years

2020
Solar Orbiter: a Sun orbiter, examining the inner heliosphere – the bubble created by the solar wind. It will be the first mission to explore the Sun's poles.

2020
Rosalind Franklin: a Mars rover with a 2m-long drill to look below the planet's surface, where biomarkers could survive the Sun's radiation.

2022
Euclid: will study cosmic structure from the second Lagrangian point (L2), looking at galaxies and clusters to a distance of 10 billion years.

2022
Jupiter Icy Moons Explorer (JUICE): a spacecraft that will examine the gas giant and its three largest icy moons; Ganymede, Callisto and Europa.

2023
Solar Wind Magnetosphere Ionosphere Link Explorer (SMILE): a joint mission with China to explore the connection between Earth and the Sun.

▸ This return orbiter will again be built by ESA. Sample collected, it will return to Earth. Once safely on the ground, these rocks will be sent to the world's premier laboratories for study.

"This represents a commitment of about €1.5bn from Europe, the first third has been approved at this ministerial," says Parker.

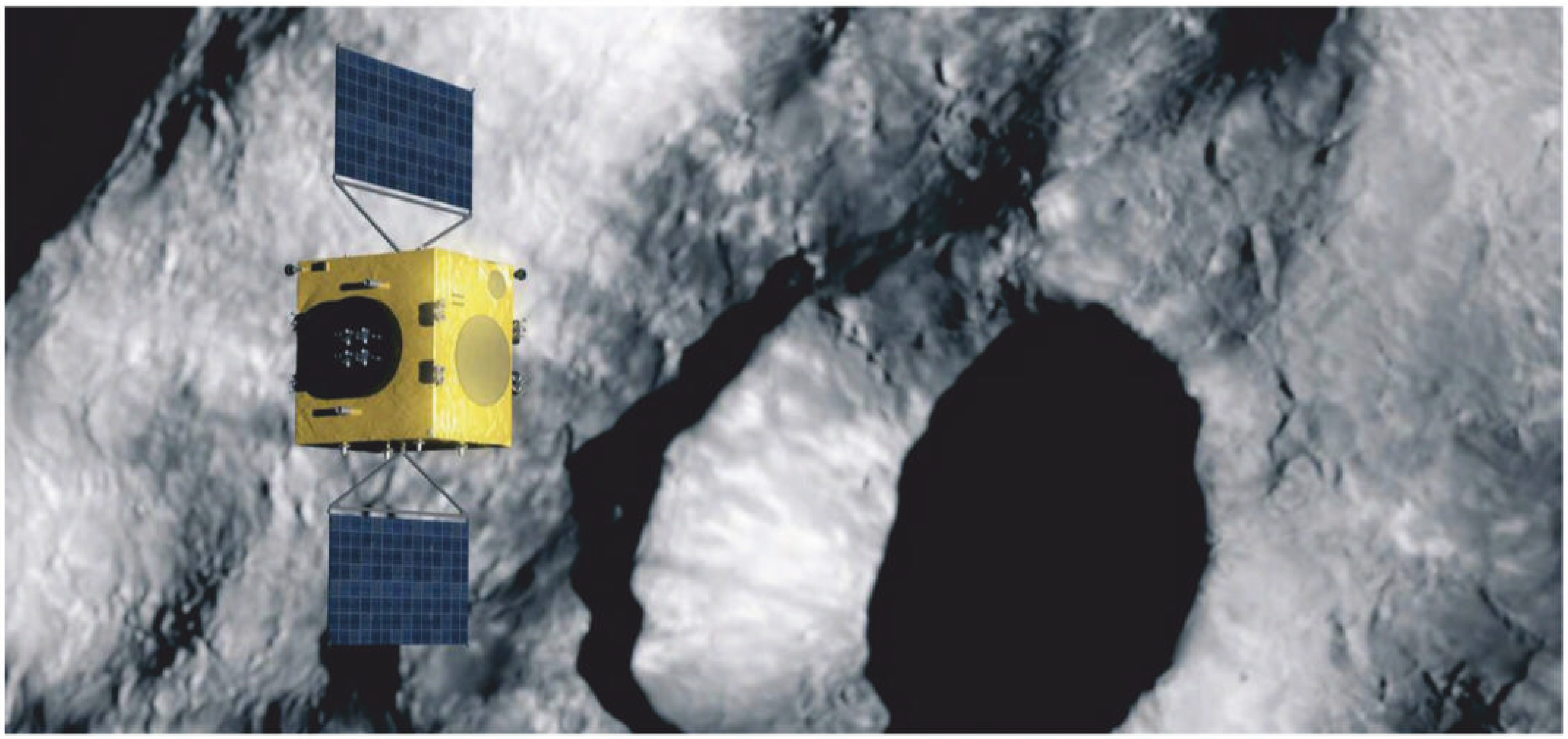
Deflecting an asteroid

As well as these long-term campaigns, the agency is mounting several stand-alone science missions. One is another joint endeavour with NASA, the Hera mission, which will investigate how we might one day deflect a potentially civilisation-killing space rock. NASA will start the project by crashing a spacecraft, known as DART, into the moon of asteroid Didymos. Earth observatories will watch the pair to see how the impact affects the Moon's orbit. Afterwards in 2024, ESA will send the Hera spacecraft to get a closer look. The initial plan was for the ESA mission to arrive before DART, but the project had to be scaled back after it failed to reach its funding targets at the last ministerial meeting in 2016.

ESA works with other nations to get European astronauts into space and the agency is keen to expand this role

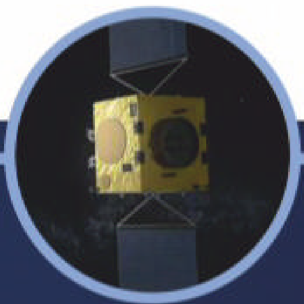
ESA is also mounting two missions that will take a look beyond the Solar System, into the distant Universe. They are part of the agency's ongoing Cosmic Vision initiative, which aims to scientifically explore all aspects of the cosmos around us.

Due for launch in 2031 is the Athena X-ray telescope. As X-ray light is only produced by extremely hot objects, Athena will be able to see the hot clouds of gas which are thought to contain most of the Universe's ordinary matter. This gas, known as



▼ Line of defence: Hera will help protect Earth from the threat of a giant rock collision

ESA/ATG MEDIALAB X 4, CAS/ESA, ESA/SCIENCEOFFICE.ORG, ESA X 4, ARIEL CONSORTIUM, NASA/JPL, EADS ASTRIUM, ESA/SCIENCE OFFICE



2024

Hera: bound for asteroid Didymos, the spacecraft will investigate how a future mission could one day deflect a civilisation-killing asteroid.

2026

Planetary Transits and Oscillations of Stars (PLATO): exoplanet-hunting mission based at L2, looking for worlds in the habitable zone of Sun-like stars.

2028

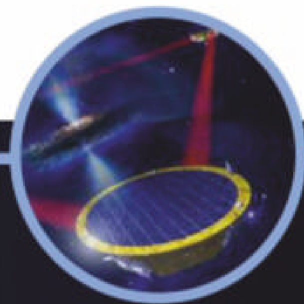
Atmospheric Remote-sensing Infrared Exoplanet Large-survey (ARIEL): will examine the atmospheres of 1,000 exoplanets from L2.

~2030

Mars Sample Return: a multi-part mission bound for the Red Planet, which will return the rock and dust samples cached by Mars 2020.

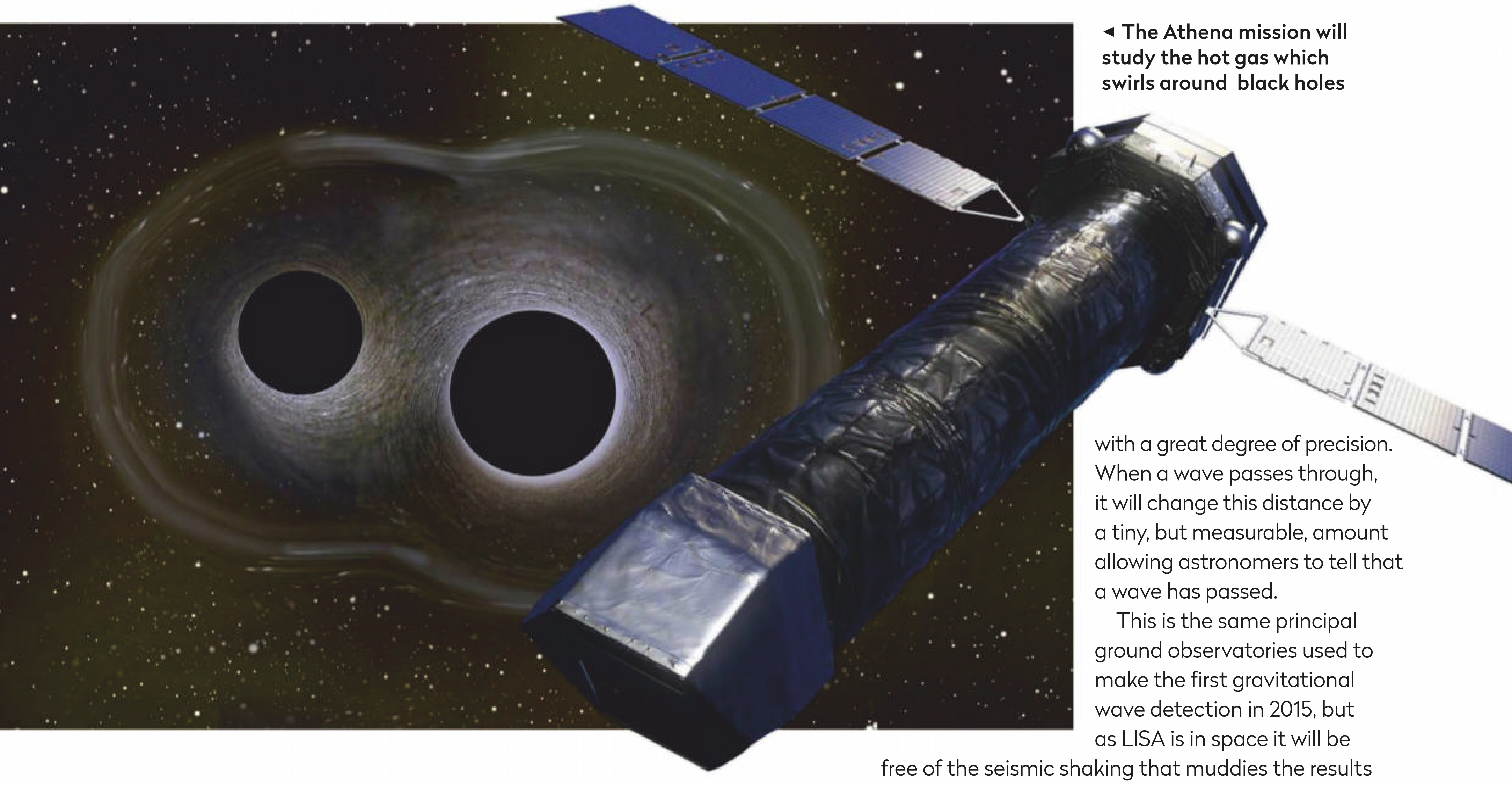
2031

Athena: X-ray telescope based at L2 that will map out hot clouds of gas throughout the Universe and around black holes.



2034

Laser Interferometer Space Antenna (LISA): a trio of spacecraft that will trail behind Earth, detecting small and weak gravitational waves.



◄ **The Athena mission will study the hot gas which swirls around black holes**

the intergalactic medium, streams between galaxies. One of Athena's main tasks is to map this out. The observatory will also look within galaxies, searching out the hot gas which swirls around the supermassive black holes at their heart.

In both cases, Athena will look deep into the Universe. These objects are so far away that we are only now seeing the light they emitted billions of years ago as the galaxies were forming, giving us a window into this critical time in the growth of the cosmos.

Finally, the ministerial meeting granted funds to develop the Laser Interferometer Space Antenna (LISA) for launch in 2034. The goal of the mission is to create a gravitational wave detector made of three separate spacecraft, flying in formation 2.5 million km apart. LISA will search for passing gravitational waves by using lasers to measure the distance between these probes with a great degree of precision. When a wave passes through, it will change this distance by a tiny, but measurable, amount allowing astronomers to tell that a wave has passed.

This is the same principal ground observatories used to make the first gravitational wave detection in 2015, but as LISA is in space it will be free of the seismic shaking that muddies the results of Earth-based detectors. This means LISA will be sensitive to much smaller waves, such as those created by collisions between stellar-sized black holes or those which have been travelling for billions of years.

While these missions are still years away from being realised, the ministerial meeting has shown that ESA and Europe have a firm commitment to becoming one of the major players in all areas of space exploration.

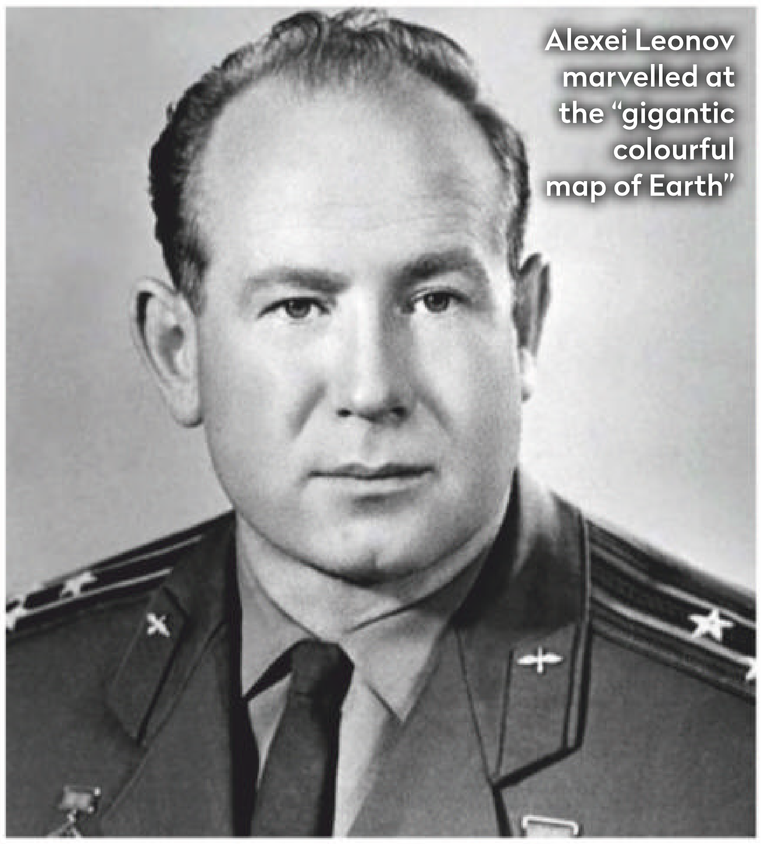
Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University

The fundamentals of astronomy for beginners

EXPLAINER

Alexei Leonov: the first space walker

55 years ago this month the first spacewalk was far from easy, explains **Nisha Beerjeraz-Hoyle**



Alexei Leonov marvelled at the "gigantic colourful map of Earth"

▲ **Stepping out: as he left Voskhod-2 in 1965, cosmonaut Leonov made history with the first ever spacewalk**

On 18 March 1965 at 08.34 UT, people in Europe and Russia stared at their TVs in astonishment as 30-year-old cosmonaut Alexei Leonov climbed out of his Voskhod-2 spacecraft orbiting above Earth and became the first person in history to perform a spacewalk.

As far as the world was concerned Leonov's 12 minutes and nine seconds floating outside the capsule – setting up and waving to a film camera that recorded the moment for posterity, tethered all the while by a 5m umbilicus – meant the Soviets were once again ahead of the US in the Space Race. But it nearly wasn't so, and it was only decades later that the death-defying drama of this historic mission came to light.

The first problems arose during pre-launch testing when Kosmos 57, an unmanned prototype sent to space to test the Soviet's new spacesuit and airlock systems, self-destructed in orbit. Nonetheless, just three weeks later the Voskhod-2 mission launched from Baikonur cosmodrome with Leonov and mission command pilot Pavel Belyayev on board.

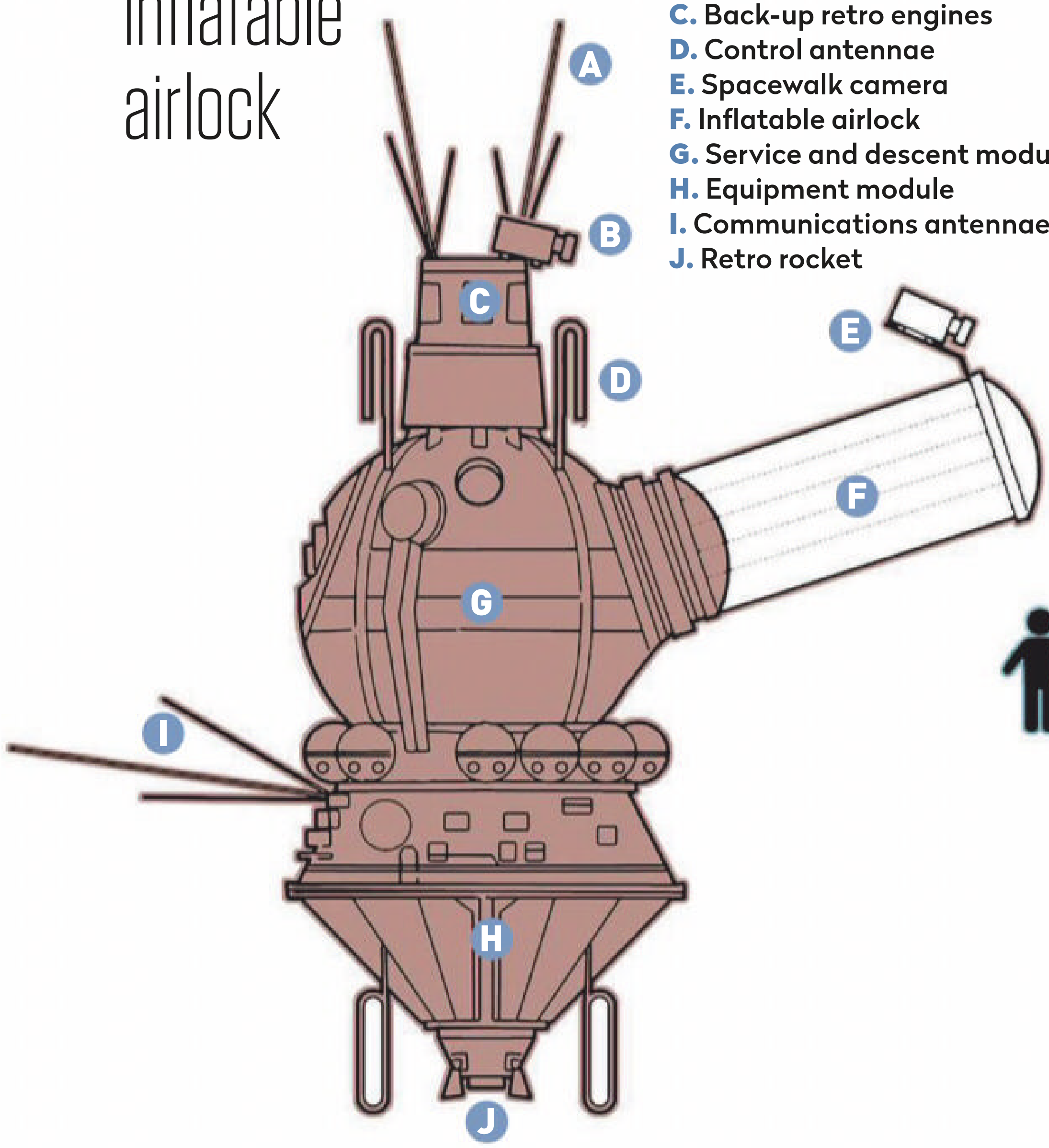
Once Voskhod-2 had completed its first Earth orbit, Leonov donned his life support backpack, while Belyayev deployed the Volga airlock, a 2.5m inflatable structure that had been designed, built and tested in nine months. After some final checks, Leonov climbed through the airlock's hatch, and shut the door. Exiting the second hatch, he activated the film camera and, safely tethered, floated into the void of space.

Leonov marvelled at the dynamic, "gigantic colourful map" of Earth below him. After 10 minutes, Belyayev

A still from the 2017 film *The Spacewalker* shows the inflatable airlock through which Leonov entered space for the first time

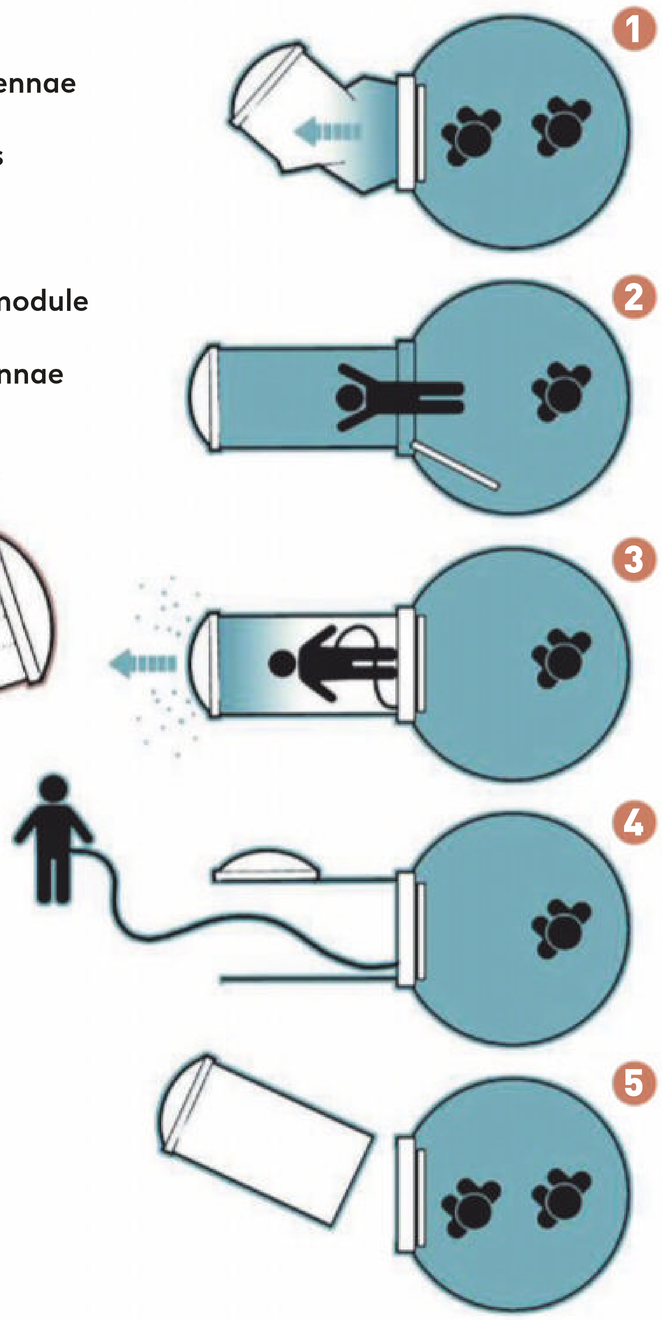
ITAR-TASS NEWS AGENCY/ALAMY STOCK PHOTO, SPUTNIK/ALAMY STOCK PHOTO X 2, TCD/PROD.DB/ALAMY STOCK PHOTO, ILLUSTRATIONS: SON OF ALAN/FOLIO

Voskhod 2's inflatable airlock



Voskhod-2

A. Communications antennae
B. TV camera
C. Back-up retro engines
D. Control antennae
E. Spacewalk camera
F. Inflatable airlock
G. Service and descent module
H. Equipment module
I. Communications antennae
J. Retro rocket



Leonov's spacewalk

1. Cosmonauts pressurise the inflatable airlock located on the side of the Voskhod-2

2. Leonov enters the airlock while Belyayev remains in the service module

3. Once depressurised, Leonov exits the airlock to begin his EVA. Belyayev watches on a TV monitor

4. Leonov spends 10 minutes outside, then returns to the airlock, where the chamber is repressurised after closing the hatch

5. Leonov returns to the service module and the airlock is jettisoned

called him to return, conscious that they were approaching Earth's night side. But Leonov's spacesuit had expanded due to the lack of atmospheric pressure and his hands and feet now floundered inside. Unable to grab the tether or fit through the hatch, he opened one of the suit's valves, purposely depressurising it and risking oxygen starvation. Sensing the difficulties, mission control cut the TV transmission.

Leonov re-entered the airlock head first, sweating profusely and fighting the symptoms of decompression sickness, but the airlock was designed for a feet-first entry so the outer hatch could be closed by hand. Already exhausted in his bulky suit, Leonov now had to turn around in the narrow shaft to seal the hatch.

At last he was back in the capsule. Respite, however, was brief. To the cosmonauts' dismay, the descent module's hatch wasn't airtight and a slow leak caused the automated systems to release more oxygen into the capsule. One rogue spark would be enough to cause a fatal explosion.

Rocky return to Earth

The next morning, the automatic guidance system that prepared the spacecraft for re-entry into Earth's atmosphere malfunctioned. The cosmonauts would have to do it manually, orientating the craft and firing the retro rockets right at the first attempt.

Leonov held Belyayev steady as he leant across the seats to check Voskhod-2's alignment using the awkwardly positioned orientation porthole. The cosmonauts scrambled back to their seats to rebalance the spacecraft for re-entry, but the delay between the two actions would land them hundreds of kilometres off-target.

As Voskhod-2 descended through Earth's atmosphere, it began to tumble. The descent module had not separated from the equipment module, and Leonov and Belyayev endured massive gravitational loads. At 100km, the modules separated. Finally, the descent module landed.

The crew found themselves in a Siberian forest, the habitat of bears and wolves. They jumped out of the capsule into snowdrifts. Leonov recalled that, "after so many emergencies, the relief at drawing breath on Earth again was indescribable".

Four hours later, a civilian helicopter located them. More aircraft attempted a rescue, but without success. Supplies were dropped – clothes, food and a bottle of cognac – but most ended up caught in trees (the cognac smashed). As darkness fell, the temperature dropped to –5°C. The following day, a rescue party on skis arrived with provisions, erected a hut and built a fire. After a second night, the cosmonauts and the group skied 9km cross-country to a helicopter that, at last, returned them to Baikonur.

Five years later Belyayev would be dead at just 44 from peritonitis. Leonov went on to be chief cosmonaut and then deputy director of the Cosmonaut Training Centre until his retirement in 1992. He died in October 2019. Their story is one of danger met with courage and determination. These days, six-hour spacewalks may be routine aboard the ISS, but it was Leonov who took that incredible first step.

▲ **Ski lift: Leonov (left) and Belyayev had to ski 9km to reach their rescue helicopter**

Nisha Beerjeraz-Hoyle is the space exploration editor of *Popular Astronomy* and a fellow of the Royal Astronomical Society

Make a panoramic spacer mount

Construct a home-built accessory to help with wide-field astrophotography

At the ready: the completed mount can hold a variety of cameras and lenses

This month's project is a camera mount to help you produce wide-field images of the night sky using a standard lens. The method involves 'stitching' together a series of smaller images to produce a large composition – often called a 'panorama'. By capturing separate but slightly overlapping shots and using photo-editing software you can create impressive images without the need to invest in expensive wide-angle lenses. The total pixel size of the resulting composite image also means you capture more detail. It is possible to achieve this without the use of a special mount, but if you have ever tried, you will know that it is common to miss small slices of sky or produce a lot of redundant data if your aiming is less than perfect.

Mark Parrish is a bespoke designer. See more of his work on his website: **buttondesign.co.uk**

To assist aiming, our mount has indexed scales for horizontal and vertical adjustments. The mount holds the camera steady while you take each image. When you are ready to move across or up to the next image you release the clamping screw, turn to the next indexed position, reclamp and shoot. By matching the scales to the chosen camera and lens during manufacture, aligning the shots required for a composition is easy.

Size matters

You don't need to get involved in maths because the downloadable spreadsheet calculator will do it for you, but thinking about the principles behind it will help you understand how it works. Digital cameras have a sensor that sits behind the lens where the film would be in a traditional camera. A full frame DSLR has a 36 x 24mm sensor, which is about the same size as 35mm film. Cameras with smaller sensors are more common and for a given lens they will pick up correspondingly smaller areas of sky. APS-C format sensors are 23.6 x 16.6mm, so their width is 65 per cent of the full-size sensor.

The focal length of the lens affects the amount of sky captured by the sensor. A long lens will capture a smaller area of sky than a short lens. A full-sized sensor will capture an image 39.6° x 27° with a 50mm lens. With a 100mm lens this drops to 20.4 x 13.7°. If you know your sensor width (S) and lens focal length (f) you can use the following calculation to work out the field of view angle (A) as follows; $A = 2 \times \arctan (S \div 2f)$. If maths isn't your thing, our spreadsheet calculates the values for you and also recommends the indexing for the two 'dials', allowing for a 10 per cent overlap for each adjoining frame edge so you should never miss a section again.

Construction is simple using our downloadable drawings, template and protractor. We clamped our finished mount to a garden table, but you could also use a tripod. For tips about out how to process your images using free software visit **bit.ly/astrophototips**.

Tools and materials

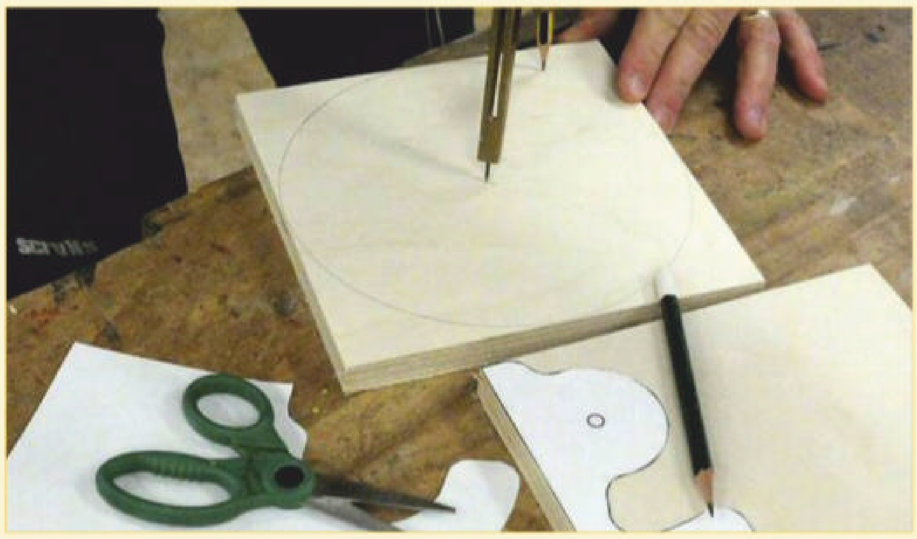
- Marking out tools (ruler, compasses and pencil), coping saw or jigsaw, drill and bits, small clamps for gluing, junior hacksaw, hole saw (approximately 30mm diameter), tin snips and pliers.
- Small sheet of thick (15mm) plywood or MDF (approximately A3 size) and a small amount of thin aluminium sheet.
- Two M6 x 40 countersunk screws with nuts and penny washers, two round nails, a dish sponge, one 1/4-20 screw for holding the camera, wood glue and epoxy resin glue.
- For the finish you'll need some sandpaper, and spray paint or varnish and lacquer to make it moisture resistant.

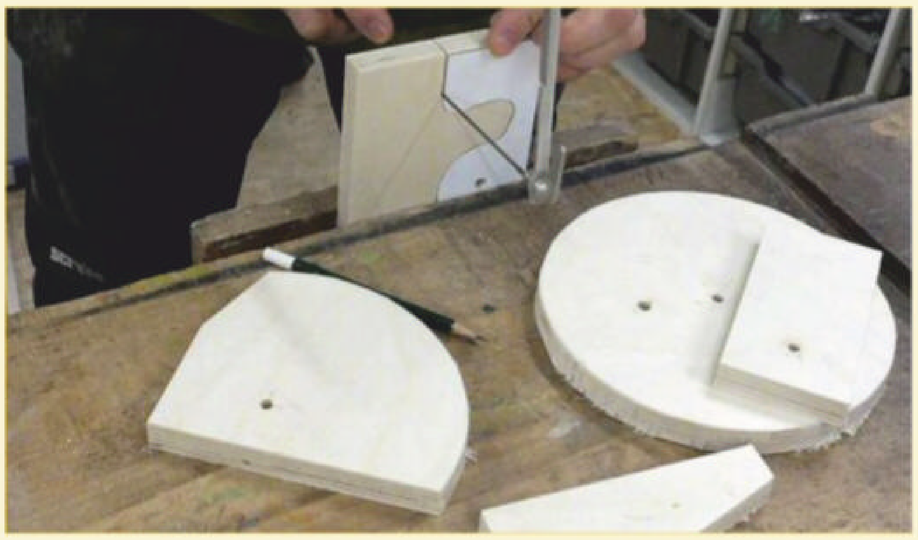
More **ONLINE**

Download the spreadsheet calculator, drawings and additional photos. See page 5 for instructions

ALL PICTURES: MARK PARRISH

Step by step



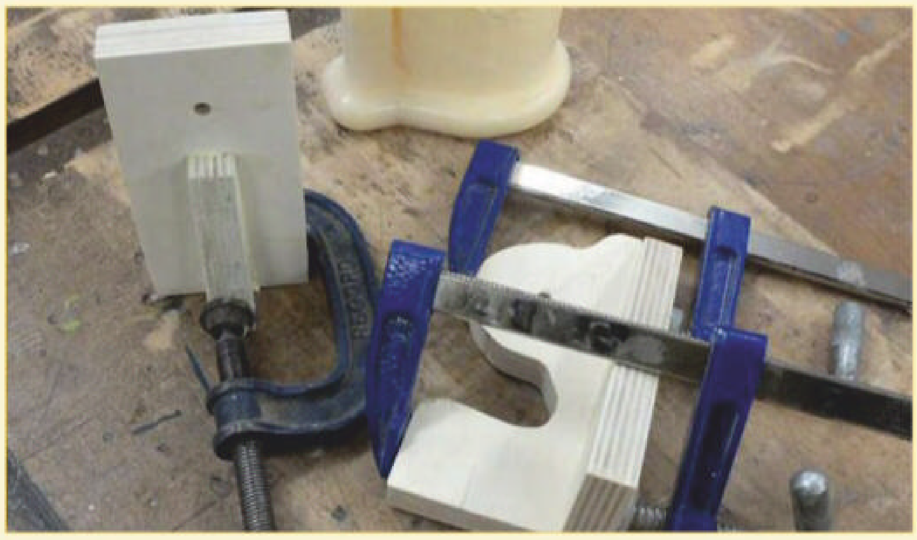


Step 1

Mark out the plywood parts ready for cutting out, using a pair of compasses to draw the circle and arc. There is a printable template for the oddly shaped top section. Drill 6mm holes for the pivot screws and a 7mm one for the 1/4-20 camera screw.

Step 2

Cut out the parts, taking particular care with the circle and arc. A jigsaw helps here, but, with patience, a coping saw can produce good results. Sand all edges so they are smooth and all the parts fit together neatly.

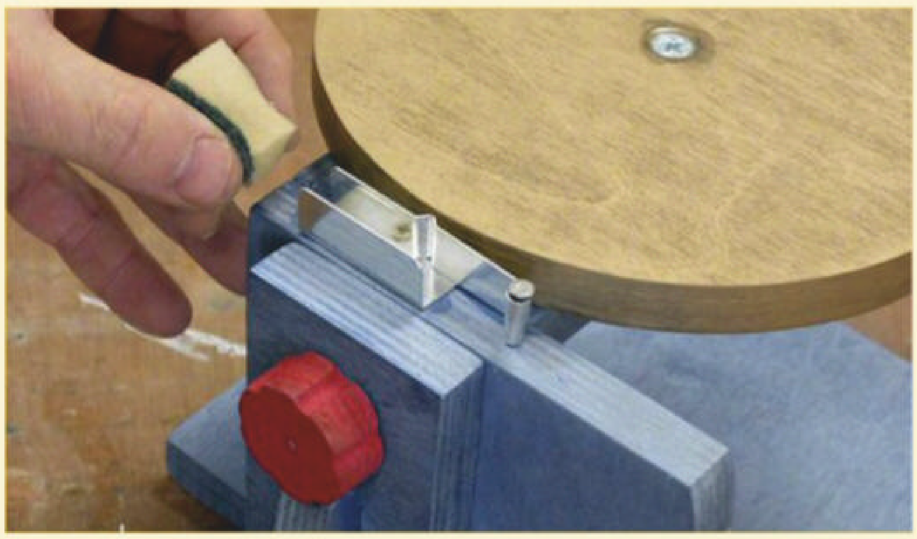


Step 3

Use wood glue to join the wedge-shaped webs to the upright bracket and the top section. We used small clamps to hold in position, but you could use masking tape instead. Once it is dry, glue the completed upright bracket to the base.

Step 4

Use a hole saw to lightly mark an offcut of plywood. Drill a ring of holes around each circumference then complete the hole saw cut to form two knobs with indents for grip. Sand down then drill out the centre and glue in an M6 nut.



Step 5

Assemble and test fit your camera using the 1/4-20 camera screw to make sure nothing fouls when it turns. After checking the parts fit and turn properly, disassemble and make sure everything is sanded down. We used spare spray paint to produce a nice finish.

Step 6

Make indexing levers from folded aluminium. The pivots are cut down nails. An offcut of sponge applies pressure. Calculate intervals for your setup and make saw cuts around the arc and disc. The ridge 'clicks' as the saw cuts pass, marking the next frame.

Take the perfect astrophoto with our step-by-step guide

ASTROPHOTOGRAPHY CAPTURE

The Moon meets the Beehive Cluster

How to catch the drama of a close pairing, while getting around the issue of the Moon's glare

The Moon will pass very close to the Beehive cluster, M44, in Cancer on 6 March (see page 46). A bright Moon close to dim cluster stars presents a good opportunity to hone your observing skills. Binoculars or a scope with a low power should reveal both objects, but the glare of the Moon will be an issue.

Moonlight is nothing more than a dimmer version of sunlight. It's light sent out by the Sun and reflected by the Moon. As the Moon has a low albedo of around 0.12, not much of the incident light gets reflected back. Albedo is a measure of how reflective a body is. In its simplest form, it indicates the percentage of incoming light which is reflected back. An albedo of 0.12 means that only 12 per cent of incident light is reflected, similar to the reflectivity of asphalt.

As moonlight is still sunlight, all of the usual effects are still present, only too dim to make their presence known. For example, with a bright almost full Moon in the sky, you can see colour around you. The sky will often glow around a bright Moon and a lot of this is to do with light scatter. During the day with the Sun above the horizon, it's the blue component of sunlight which scatters. We see blue light coming from all directions and the sky appears its characteristic colour.

At night, even with a bright Moon in the sky, we don't see the sky as blue because the colour is too dim. However, a camera can still record it. As an exercise, when the Moon is bright and high in the sky, take an extended exposure of your garden or neighbourhood with some sky in the frame. If your exposure is correct, it will look like it's been taken in the middle of the day.

Let it shine: you can combine several techniques to get your final image

For dim background objects, the Moon's glare can be an issue. Thin cloud proves especially unhelpful, providing an illuminated veil which the camera will dutifully record instead of the background stars. Even if it's clear with no cloud, a high moisture content in the atmosphere can enhance the Moon's glare significantly, again hiding any dim background objects.

Another issue is dew on optical surfaces. If your camera or scope lens appears a bit misty, moonlight will illuminate this and the sky around the Moon will be overexposed.

Capturing both the Moon and the Beehive is a tricky challenge. If you attempt to correctly expose for the Moon, the Beehive stars will be too dim to be recorded. Alternatively, you could go for broke and deliberately over-expose the Moon to reveal the cluster. With a bit of photographic skill, this can be quite a dramatic shot. Finally, there's also the high-dynamic-range (HDR) option where you combine shots to produce an image which shows the Moon properly exposed as well as the cluster stars.

As you can see there are lots of decisions you need to make. One way around this is to cover all options and capture everything you need to enable you to build any of the image types mentioned.

▸ ***See page 46 for timing information about this event***

Pete Lawrence is an expert astro imager and a presenter on *The Sky at Night*

Recommended equipment: DSLR camera with a lens or attached to a scope (see Step 1 for focal length)

✉ Send your images to: gallery@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

STEP 1

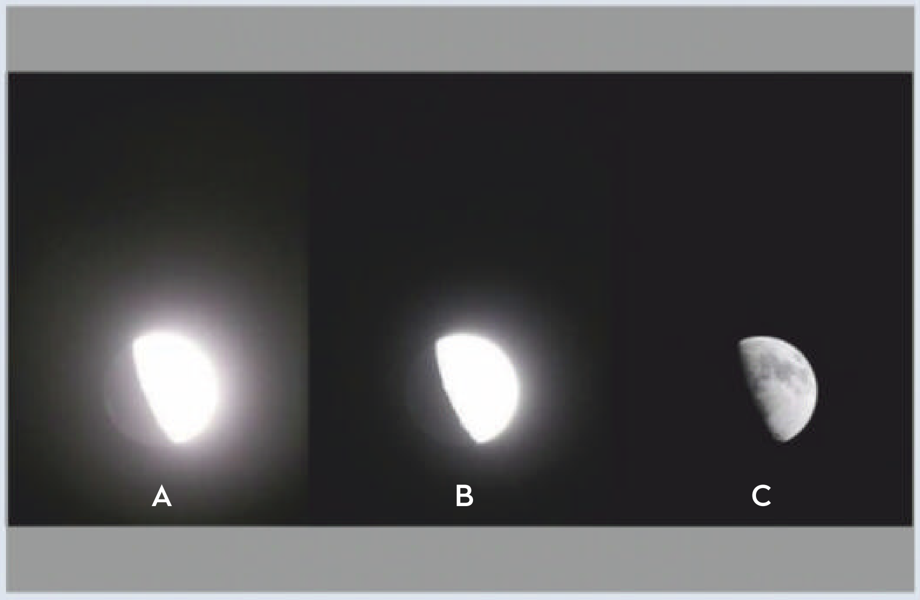
Assess the best lens focal length. At closest approach a minimum vertical scale of 2.5° is required to capture both Moon and cluster with a border. For a landscape orientation, use up to a maximum of 300mm or 500mm lens for non-full or full frame cameras respectively. For portrait, the values are 500mm or 800mm.

STEP 2

A simple tripod will work, but if you want to work with a low ISO for better tone and lower noise (unwanted artefacts) a tracking mount is better. If you use a tripod, increase the ISO to achieve shorter exposures that avoid motion blur. Focus accurately on a bright star; nearby examples are Castor, Pollux or Regulus.

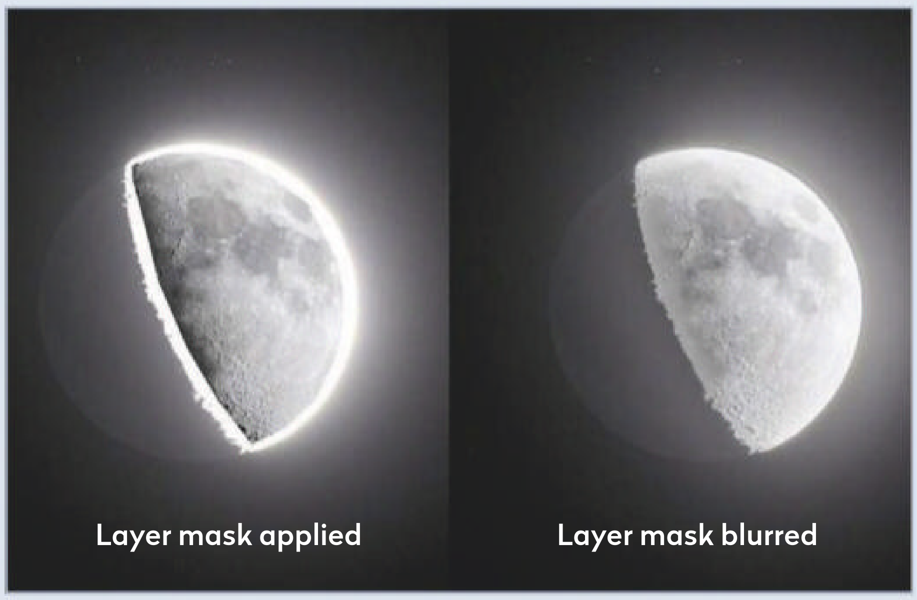
STEP 3

Line up with the Moon in the upper part of the image frame. For the first shot, try with the ISO set to 400. If using a camera lens, set the aperture to the lowest f/number and then wind it back by a couple of stops to avoid possible aberrations. Finally, begin with the exposure set to 1 second and get ready to adjust.



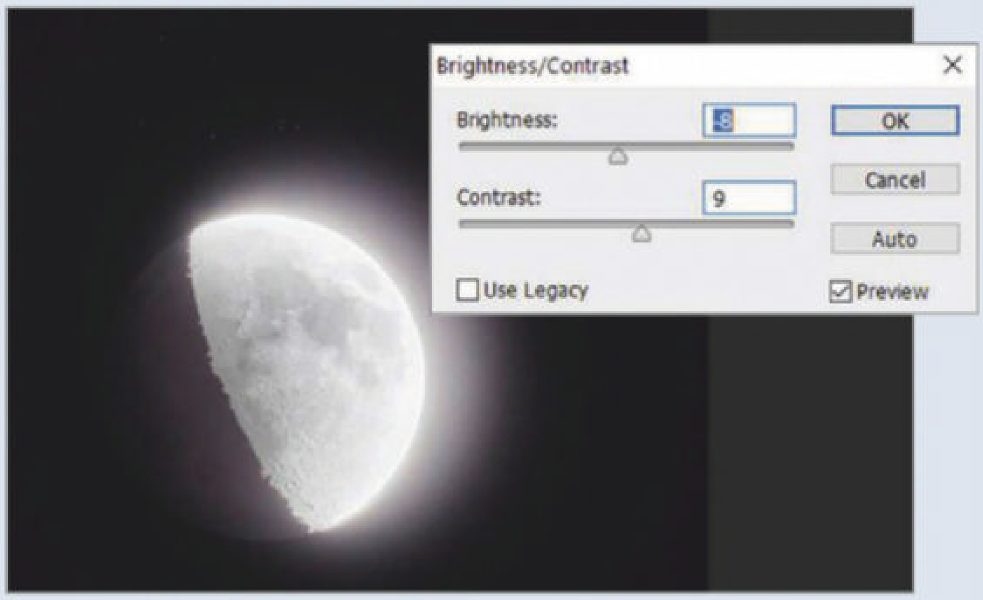
STEP 4

Take the shot and examine. The result will depend on your setup. If you can't see the cluster stars, increase exposure or ISO depending on whether you're on a tracking mount as mentioned in Step 2. Aim for three shots – one with clear stars and over-exposed Moon (A), another with it just over-exposed (B), and a correct exposure (C).



STEP 5

Load images into an editor as separate layers, (C) top, (B) middle and (A) bottom. Align them and draw a selection area slightly inside the bright lunar disc. Invert the selection, copy and paste as a layer mask. Apply a fairly severe Gaussian blur to the mask so images look more natural. You may need to curve adjust (B) to achieve this.

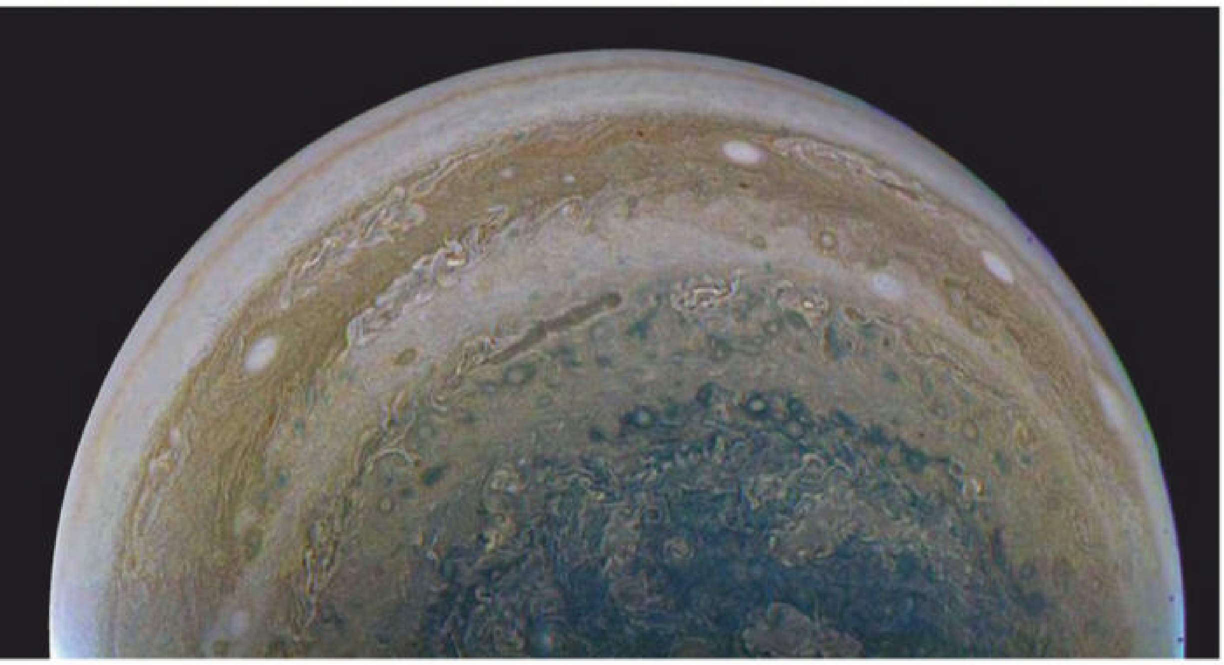


STEP 6

Merge (C) and (B) to create (D). Draw a circular selection just inside the Moon's edge on (D), invert the selection and copy and paste as a layer mask again. Apply another Gaussian blur to soften and blend the layer mask edges. Try to achieve a reasonably natural look. Apply final tweaks of brightness and contrast until you're happy.

How to process images from space mission data

Publicly available RAW data can be processed to create beautiful images of planets



▲ The final processed JunoCam image of Jupiter

Stunning images of distant worlds in our Solar System taken by the Hubble Space Telescope or planetary orbiters are captured in a RAW data format which is free to download. In this guide, we'll use RAW data captured by NASA's Juno mission at Jupiter to show you how to process your own space mission images. If you are successful you might want to enter the Insight Investment Astronomy Photographer of the Year competition's new category, the Annie Maunder Prize for Image Innovation (see box on opposite page), which will be awarded to the best image processed from publicly available data.

NASA's Juno probe is equipped with JunoCam, a high-resolution camera for imaging Jupiter as never before. What is different about JunoCam is that the RAW data is uploaded to the Juno website and is readily available for anyone to process. There is also a forum where members can discuss storms and surface features, vote for targets for JunoCam to image and discuss results. The RAW data is placed on the site for members to download and re-upload for NASA and other members to view. All this is free of charge.

To begin processing your images you need to access the Juno website and create an account (see Stage 1 picture). This is done by going to **www.missionjuno.swri.edu/junocam** and clicking on 'login' in the top right corner of your screen. At this point you will be asked to create a username and password. Once you have done this, click 'Image Processing' and you will arrive on a page where you can access RAW Juno data and see user-uploaded images. To access the full library of RAW images, click 'More from JunoCam' on the right-hand side of the page (below the section entitled 'Most recent from JunoCam').

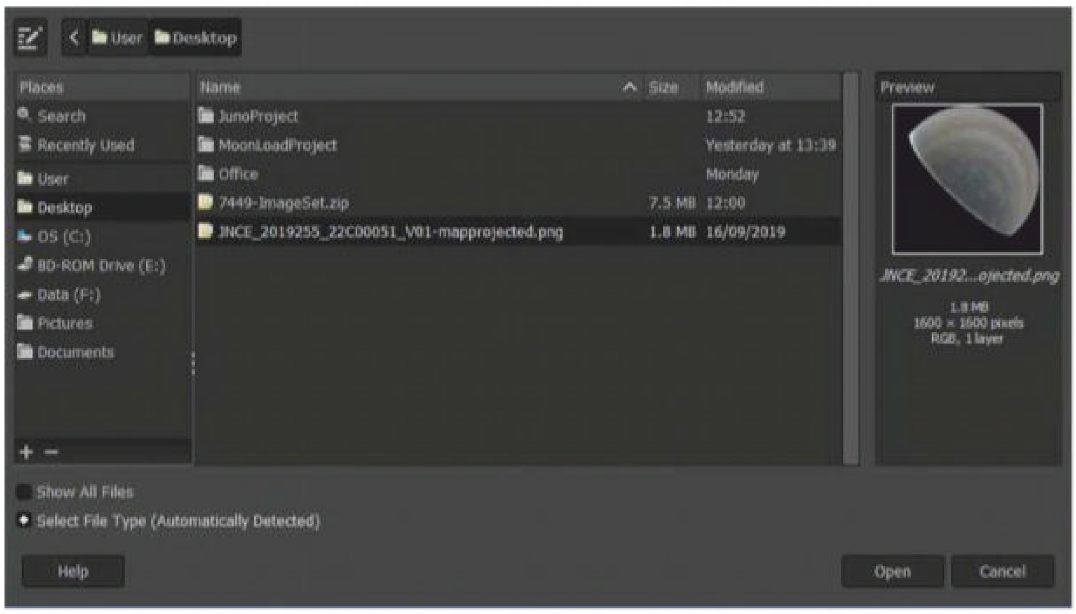
Using the library

The library page will open up and there are options for selecting different sets of images. A number at the top of the page (eg '1/67') indicates how many pages of data are available, and this will increase as Juno makes more passes of the gas giant. Select the image you would like to process by clicking on it and this will open the download window. Select and download the image set to your computer.

The image set will download in .zip format so you will need to unzip it and store the files on your hard drive. Once unzipped you will see the blue channel, green channel, red channel, RAW channel and map-projected channel images. You can use the red, green and blue images and combine them in Photoshop or other graphic manipulation programs to make an RGB image. The RAW contains slices and requires custom-written

▼ Stage 1: start by setting up an account on the JunoCam website

ALL PICTURES: PETER WILLIAMSON



▲ **Stage 2: use GIMP to open the map-projected image from its location on your computer**

software. For the purposes of this project we will use the map-projected.png file, which is an RGB combined image. When you open it, you will see that the image is dull and bland. We'll show you how to enhance this image to show Jupiter in a more natural, realistic way.

We used GIMP, a free graphic manipulation program, to adjust levels of dark and light within the image. Other graphic manipulation programs are available, including Photoshop, but any product that allows curves and levels to be adjusted will work with this project. Open GIMP and then click 'File › Open' and select the map-projected image from its location on your PC (see Stage 2 picture). Once the image is loaded, click 'Colour' from the menu and then select 'Levels' (see Stage 3 picture). Now the image depth and brightness can be manipulated. Adjusting the options on the input levels section will bring out the

Peter Williamson is an astronomy broadcaster and co-founder of the UK's annual Solarsphere Festival

Insight Investment
Astronomy Photographer of the Year

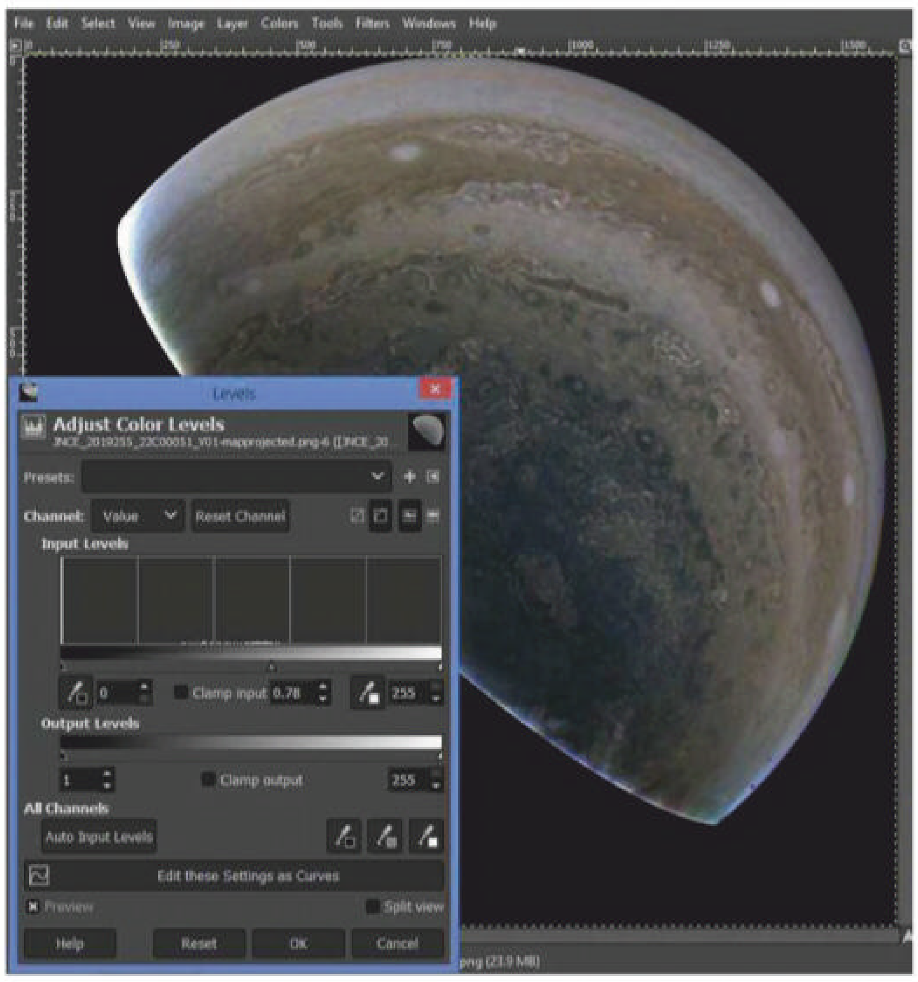
Annie Maunder Prize for Image Innovation

More and more professional observatories on Earth and in space are making their data open access. A new category in the Insight Investment Astronomy Photographer of the Year competition is inviting astronomers to take this RAW data and process it themselves. You can enter the category at: **rmg.co.uk/astrophoto-2020**

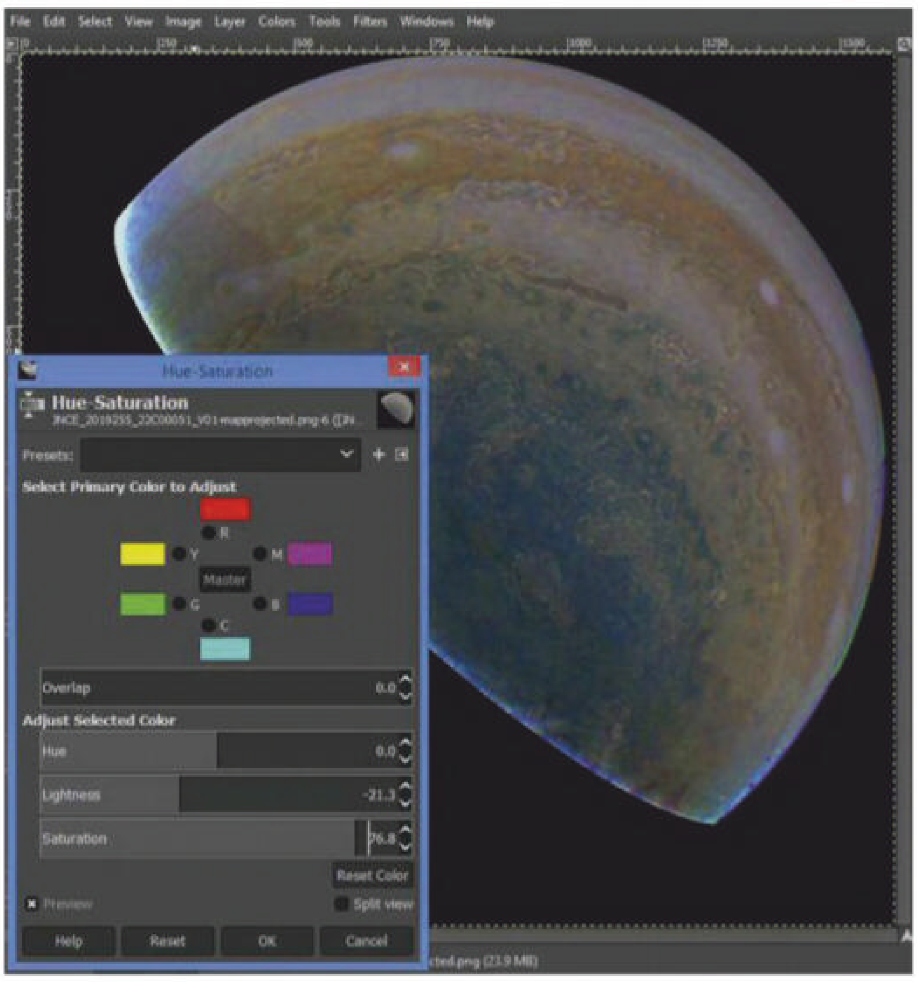
cloud belts and darken the dark areas, creating an enhanced 3D look. The amount of processing that is applied is up to you, but a light touch will often give good results.

Having adjusted the levels, it is now possible to adjust the saturation of the overall image or individual colours. To do this click 'Colour › Hue-Saturation'. This will open the manipulation window (see Stage 4 picture). Each colour can be clicked on to manipulate the master image for the overall desired effect. Once clicked, use the 'Lightness' and 'Saturation' sliders to adjust to the desired level. Do not adjust the 'Hue' slider unless you wish to create false colour. After this process is complete, it may be desirable to redo 'Levels' again depending upon personal taste.

Final processing can involve rotating, trimming and cropping the finished image by selecting 'Tools' from the main menu to make adjustments to give a more pleasing completed image, which can be seen at the start of this article.



▲ **Stage 3: use 'Levels' to adjust depth and brightness of the image**



▲ **Stage 4: adjust the saturation of the image or individual colours**

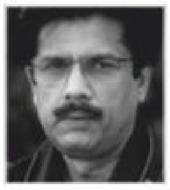
Your best photos submitted to the magazine this month

ASTROPHOTOGRAPHY GALLERY

More **ONLINE**
A gallery containing these and more of your images

◁ Ring of fire

Premjith Narayanan, Bahrain, 26 December 2019



Premjith says: "In December, Bahrain witnessed the deepest solar eclipse in more than 100 years. This time the Moon was at its apogee and visually smaller than usual, causing this annular eclipse or 'ring of fire'. In Bahrain it was partial. It was cloudy on the horizon and so the rise of the eclipse (6.22am AST, Arab Standard Time) could not be seen clearly. Five minutes later it crept out slowly, gleaming red. As more light from the Sun was revealed, the colours started changing vividly from dark pink to red and orange. At 6.36am AST the Moon reached maximum coverage over the Sun's disc at 90.6 per cent, and had this nice, thin 'C' shape. It was a once in a lifetime experience."

Equipment: Canon EOS R mirrorless camera, Canon EF 300mm f/2.8L IS USM lens
Exposure: ISO 200, f/2.8, 1/1000"

Premjith's top tips: "As the light intensity was not so pronounced, I took photos without filters, but I used the camera's 'live view' mode so that my eyes were not impacted directly. When the Sun is more visible and the horizon effect is lessened, filters and glasses are essential to protect your eyes. I selected a portrait frame to include the waters and the clouds above reflecting the light."

Horsehead and Flame Nebulae ▷

Adam Jeffers, Cookstown, County Tyrone, 4 February, 26 October 2019

Adam says: "I had to wait almost nine months to complete this image. Between the weather and the Moon, deep-sky imaging can be a real challenge. However, being able to produce an image of the iconic Horsehead Nebula under local skies is very rewarding."

Equipment: Atik 383L+ and QHY9 mono CCD cameras, Sky-Watcher 80ED Pro refractor, Takahashi Epsilon 180ED astrograph, Sky-Watcher EQ6 mount **Exposure:** 50x300" L, 15x300" R, 15x300" G, 13x300" B **Software:** AstroPhotography Tool, AstroPixel, Photoshop

◁ New Year's Moon

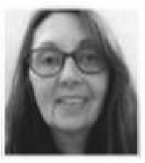
Julie Straayer, Queensland, Australia, 1 January 2020

Julie says: "This is the six-day old, 32%-lit Moon from Coolum Beach in Queensland. The skies were clear at times with intermittent cloud, but the Moon looked beautiful and I couldn't resist my first New Year lunar shot."

Equipment: Samsung Galaxy S9 phone, Sky-Watcher 102mm Maksutov, AZ-GTi mount **Exposure:** ISO 50, f/1.5, 1/90" **Software:** Aviary

△ Star trails

Verity Stannard, Herstmonceux, East Sussex, 22 December 2019



Verity says: "The former Royal Greenwich Observatory at Herstmonceux was built to be north–south aligned. This enabled me to place the north celestial pole above dome D (seen in the centre). The Ursid meteor that streaked through (lower left) was a bonus and made all the work worthwhile."

Equipment: Sony Alpha 6000 camera **Exposure:** ISO 800, f/3.5, 92x120"; 20 dark frames **Software:** PIPP, Sequator, Lightroom, Photoshop

◁ Keyhole Nebula

Nova Edgcombe, Auckland, New Zealand, 4 December 2019

Nova says: "Since moving from the Northern to Southern Hemisphere, the Carina Nebula has become a favourite target. The Keyhole is a dark nebula created by the dying star Eta (ε) Carinae, which is visible here to the Keyhole's left."

Equipment: ZWO ASI 294 MC Pro camera, Celestron EdgeHD 9.25-inch Schmidt-Cassegrain, Sky-Watcher EQ6-R Pro mount **Exposure:** 93x60" **Software:** Nebulosity, Photoshop

△ Partial solar eclipse

Omid Qadrdan and Ahmad Riahi Dehkordi, Hengam Island, Iran, 26 December 2019

Omid says: "We had to travel nearly 1,900km to get to the exact place that I had planned to capture the eclipse. The night before, we couldn't sleep, we were so excited for the next morning. As the crescent Sun rose on the horizon and a fishing boat passed right across our view and made this scene, we knew the trip was worth every second."

Equipment: Canon EOS 6D Mark I DSLR camera **Exposure:** ISO 640, 1/1250"

Andromeda Galaxy ▷

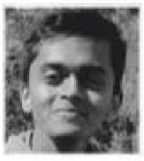
Nick Berry, Gloucestershire, 25 December 2019

Nick says: "This was my first time using this equipment, indeed my first time imaging a deep-sky object with a telescope, so I was happy with the result as sky conditions weren't great."

Equipment: Canon EOS 650D DSLR camera, Sky-Watcher 72ED refractor, Sky-Watcher HEQ5 Pro mount **Exposure:** ISO 800, 50x2', 25x darks, 30x flats, 50x bias **Software:** DeepSkyStacker, Photoshop

△ Triangulum Galaxy

Mukund Raguram, California, US, 1 & 2 November 2019



Mukund says: "M33 was one of the first objects I saw through a telescope and remains one of my favourite DSOs to image. I captured seven hours of data over two nights, travelling to two local dark-sky parks. My greatest challenge was in processing – M33 is big and bright, but I found it difficult to produce a natural look."

Equipment: ZWO ASI 1600MM camera, Explore Scientific ED127 apo refractor, EQ6-R Pro mount **Exposure:** 25x180" RGB, 64x180" L, 40x 300" Ha **Software:** NINA, PixInsight

Flaming Star and Tadpole Nebulae ▷

Tom Wildoner, Pennsylvania, US, 25 November 2019

Tom says: "I've chosen this view to test out my new camera: the Flaming Star is the comma-shaped one on the top; the Tadpole is the large, circular nebula near the centre. The open cluster, M38, is also there, in the bottom left corner."

Equipment: ZWO ASI 071MC-Pro, William Optics RedCat 51 refractor, Celestron CGEM DX mount **Exposure:** 2-frame mosaic, each 24x300" **Software:** Sequence Generator Pro

ENTER TO WIN A PRIZE. HERE'S HOW:

Whether you're a seasoned astro-photographer or a beginner, we'd love to see your images. Email them to **contactus@skyatnightmagazine.com.** Ts&Cs: www.immediate.co.uk/terms-and-conditions

We've teamed up with Modern Astronomy to offer the winner of next month's Gallery a Finder-Guider Adaptor, which connects T-thread guide cameras from ZWO, Orion and others to 9 x 50 standard finders from Sky-Watcher. The accessory comes with full instructions and support. **www.modernastronomy.com • 020 8763 9953**

The best in equipment, accessories and books each month

REVIEWS

Find out more about how we test equipment at **www.skyatnightmagazine.com/scoring-categories**

86

We tested the Celestron Advanced VX 700 Maksutov-Cassegrain on a range of lunar targets. How did it get on?

PLUS: Books on the greatest scientific minds, Galileo for kids, and a round up of the latest must-have gear

@THESHED/PHOTOSTUDIO

HOW WE RATE

Each product we review is rated for performance in five categories. Here's what the ratings mean:

★★★★★ Outstanding ★★★★★ Very good ★★★★★ Good ★★★★★ Average ★★★★★ Poor/avoid

Our experts review the latest kit

FIRST LIGHT

Celestron Advanced VX 700 Maksutov-Cassegrain telescope

Get up close and personal to your celestial targets with this easily handled scope

WORDS: PETE LAWRENCE

VITAL STATS

- **Price** £2,395
- **Optics** Maksutov-Cassegrain
- **Aperture** 180mm (7-inch)
- **Focal length** 2,700mm (f/15)
- **Mount** Advanced VX German equatorial
- **Weight** 8.6kg (optical tube assembly), 7.7kg (VX mount head), 8.2kg (tripod)
- **Counterweights** 2 x 5.4kg
- **Supplier** David Hinds Ltd
- **Tel** +44 (0)1525 852696
- **www.**dhinds.co.uk

As we begin the review of the Celestron Advanced VX 700 Maksutov-Cassegrain, here's a quick refresher on some terminology. The term 'catadioptric' describes using lenses and mirrors to shape incoming light in a telescope. The popular Schmidt-Cassegrain telescope (SCT) is a catadioptric, as is the Celestron model we're reviewing here. 'Cassegrain' refers to the combination of a concave primary mirror and a convex secondary, while 'Maksutov' refers to the shape of the instrument's front corrector plate. Both Schmidt-Cassegrain and Maksutov-Cassegrain telescopes use primary mirrors, which are sections of a sphere. Such mirrors suffer from spherical aberration, producing poor off-axis focus (coma). This is countered in SCTs by using flat corrector plates with a slight aspheric curve; 'aspheric' means the curvature is not a portion of a sphere. Maksutov-Cassegrains make use of highly curved correctors which are part of a sphere. These are thicker than their SCT equivalents and typically require greater cool down times. The Maksutov-Cassegrain design also produces a longer natural focal length compared to a similar-sized SCT. Celestron's VX 700 Maksutov-Cassegrain is an f/15 instrument with a focal length of 2,700mm. This makes it ideal for getting close views of the planets and the Moon, but it's not so great for large deep-sky objects.

Tried and tested

During testing we took a tour around the Moon's surface using the supplied 28mm eyepiece. The views were excellent; there was lots of detail and the contrast between the bright highlands, dark lava seas and deep black shadows was impressive. The shadows cast by the lunar Alps were dramatic and reminiscent of being cast by a giant cathedral. Under poor seeing and using the supplied medium power eyepiece, lots of fine detail was discernible, including both craters within 57km Cassini – 17km Cassini A and 9km Cassini B.

Although the long natural focal length isn't optimal for large deep-sky objects, the telescope performs ▸

Easy handling

The Maksutov-Cassegrain design produces a powerful, long focal length instrument in an easy to handle package. Lifting the scope on and off the VX mount was easy. The thicker meniscus Maksutov corrector means you need to leave a bit more cooldown time, but for this 7-inch instrument we found this didn't need to be more than 60–90 minutes. We loved the long focal length, it's something that becomes addictive. Being a slow instrument, it's best suited for brighter objects, but even with a fairly modest eyepiece you get a fairly close-up view of your target. For the planets or the Moon, this is an excellent portable telescope.

The secondary mirror is a silvered portion of the inside surface of the corrector plate. For this 7-inch scope the silvered circle measures 42mm, which is 23.3 per cent by diameter of the corrector (5.43 per cent by area). Views through the eyepiece revealed excellent contrast, with black shadows inside lunar craters being a memorable sight during testing. The corrector has StarBright XLT optical coating, which helps contrast.

ALL PICTURES: @THESHED/PHOTOSTUDIO

8x50 finderscope

A long focal length instrument such as this requires a good finderscope. Celestron provide an 8x50 straight through finderscope which may be connected to the main optical tube assembly via a small shoe and clamp arrangement. We found this finder worked well, but an illuminated cross-hair upgrade would have been even better.

Tripod

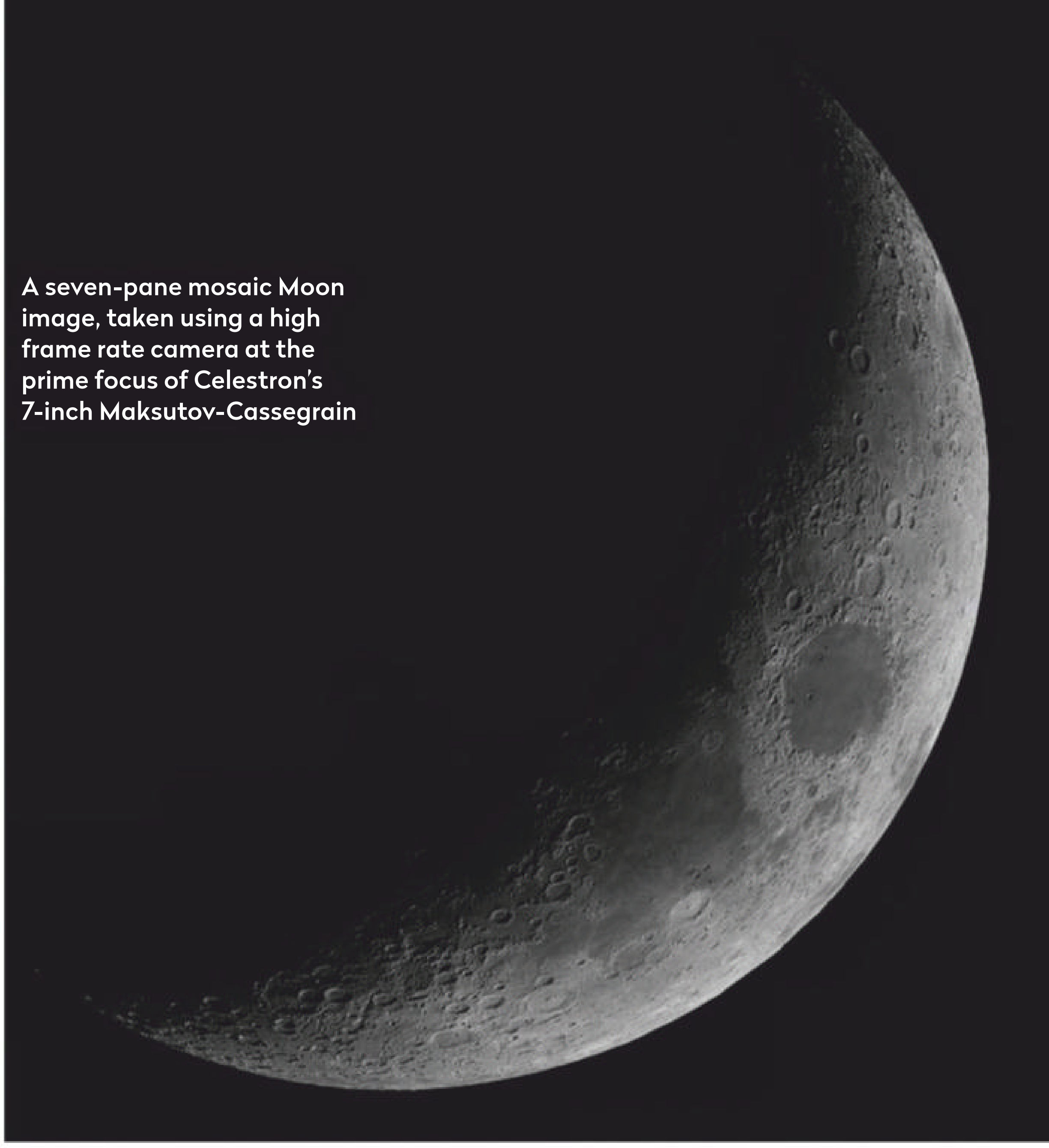
The scope and mount head sit on a sturdy tripod. Each leg has a diameter of 50.8mm and the tripod assembly permits height adjustment between 1,118mm and 1,626mm. We found the combination of the supplied tripod, VX mount and optical tube assembly worked very well, offering good stability even at large image scales.

NexStar+ Go-To computer

The VX mount is controlled via Celestron's NexStar+ hand controller. We were very impressed with the Go-To accuracy of this mount. After a two-star align with two further calibrations, our test targets centred every time. The available alignment options are two-star, one-star, Solar System, last- and quick align. The on-board database offers over 40,000 Go-To targets.

Advanced VX mount head

The Celestron Advanced VX mount is a sturdy equatorial telescope platform. Adjustable for 7–77° latitudes, it comes with both a declination (dec.) and right ascension (RA) drive. It supports three auxiliary ports, one of which is used by the NexStar+ handset. The design uses DC servo motors and offers permanently programmable periodic error correction. It's not the quietest mount when slewing.


A seven-pane mosaic Moon image, taken using a high frame rate camera at the prime focus of Celestron's 7-inch Maksutov-Cassegrain

KIT TO ADD
1. Celestron PowerTank Lithium
2. Celestron StarSense AutoAlign
3. Celestron NexYZ 3-Axis universal smartphone adaptor

► very well on smaller ones. We could discern some of the nebulosity within the Running Man Nebula, NGC 1977, and the Crab Nebula's squashed, irregular shape was seen easily using direct vision. One thing to bear in mind if you're into astrophotography is that f/15 is quite slow, meaning you'll need longer exposures to match the exposure depth of faster instruments.

Other test views of the Ring Nebula, M57, were fantastic. Its glow was evident, and you could make out the dark inner portion with direct vision. As Albireo was up in the night sky we conducted a colour test and there were no problems. The warm gold-yellow of the primary contrasted well with the blue-hued secondary. Meanwhile, the Orion Nebula, M42, showed a wealth of detail with contrast being held across the unevenly illuminated gas of the nebula.

All the benefits

An 8x50 finderscope is supplied and it's essential to get this fitted and aligned as soon as possible. The optical tube is supplied with a CGE (Losmandy-compatible) dovetail bar and this was easy to attach to the VX mount head. Our only, slightly picky, gripe with the optical tube was the annoying plastic dust cover which fell off far too easily. When it does stay on, the cover is slightly convex meaning you can't stand the tube on its end. We found the focuser to be adequate, but image shift does occur when winding in different directions. This is evident at large image scales.

The scope is part of the package, including a tripod and a Celestron VX mount head. This is a well-constructed piece of kit, and it's well-suited to a 7-inch Maksutov-Cassegrain. The mount head isn't overly heavy and the whole setup is portable and easy to assemble on your own.

Overall, our experience with the Celestron Advanced VX 700 Maksutov-Cassegrain was good and we can heartily recommend it. However, just be aware that a 2.7 metre (2,700mm) focal length can require careful management. Fit a 2x Barlow and your effective focal length is 5.4 metres! If you're looking for wide vistas of the heavens, this is not the scope for you. But if you want to get up close and personal to your targets, this instrument will help you do this confidently.

VERDICT

Build & Design	★★★★☆
Ease of Use	★★★★☆
Features	★★★★☆
Go-To/Tracking accuracy	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

Focuser and visual back

Focusing is achieved using a rotating knob on the back of the optical tube. High precision focusing is marred slightly by image-shift which occurs when the focus knob is rotated in different directions. The visual back supports 2-inch equipment, or 1.25-inch barrels via a supplied 2-inch to 1.25-inch adaptor.

@THESHED/PHOTOSTUDIO, PETE LAWRENCE

Our experts review the latest kit

FIRST LIGHT

Opticron Imagic IS 12x30 binoculars

An all-round pair of binoculars with an impressive image-stabilisation system

WORDS: STEVE TONKIN

VITAL STATS

- **Price** £519
- **Optics** Fully multi-coated
- **Aperture** 30mm
- **Magnification** 12x
- **Prisms** Roof (internal) and Porro (eyepiece turrets)
- **Angular field of view** 5°
- **Focusing** Centre focus, moving internal lens group
- **Eye relief** 15mm
- **Interpupillary distance (IPD)** 54-74mm
- **Weight** 537g
- **Supplier** Opticron
- **Tel** +44 (0)1582 726522
- **www.**opticron.co.uk

A new player in the world of image-stabilised binoculars is bound to be of interest, so we were eager to find out how Opticron's latest model, the Imagic IS 12x30, performed. We were far from disappointed.

Like all image-stabilised models, the Imagic IS 12x30 binoculars have a one-piece body with adjustable eyepiece turrets. The binoculars come with a tough, lined and padded vinyl case, a comfortable neoprene neck strap and a choice of individual eyepiece caps or a tethered rainguard. Both options fit well, although there is no cap for the objective lens end. The set is completed with a good quality microfibre cloth in a wallet, a comprehensive instruction booklet and an intriguing 'anti-flip' loop.

Body strength

The body is covered with a textured nitrile rubber armour that gives a very secure grip, even when it is damp, and also offers some protection against the inevitable bumps to which all well-used binoculars are subjected. There are internal roof prisms and a Porro prism system in each of the eyepiece turrets, which you rotate in order to adjust the interpupillary distance (IPD) – the distance between the centres of the pupils of the eyes. The eyepieces move smoothly and are stiff enough to prevent inadvertently changing the IPD. They are specified as IPX-4, meaning they are splash proof. The focuser is near the objective lens end of the body and is light, smooth and without backlash. The right eyepiece dioptre adjustment is suitably stiff and also moves smoothly. The image stabilisation is activated by a switch on the top of the body. These are robust binoculars with good ergonomic design.

The four-position eyecups twist down to 2mm above the surface of the eye-lenses, so only 13mm of the specified 15mm eye relief is available. This was just enough to be able to see the entire 5° field of view when we wore spectacles. If you prefer observing without spectacles, there is enough focal range either side of infinity focus to accommodate visual focal defects, and the 2.5mm exit pupil is small enough to reduce the effect of mild astigmatism (an imperfection in the curvature of the eye's cornea).

The image-stabilisation technology makes focusing a doddle. There's no region of 'is it or isn't it'; ▸

Superb sky views

Opticron's image stabilisation (IS) system was developed in collaboration with a leading Japanese optical systems designer. It is activated by a small lever on a rotary toggle switch that is conveniently placed for operation with your right forefinger. Instead of time-out circuitry, there is a small green LED that is immediately apparent when you take the binoculars away from your eyes, reminding you to switch the system off.

The IS system is based around gimbal-mounted prisms and is specified as being able to correct for instability with an amplitude of up to 3°. It's effective at eliminating rapid, low magnitude 'shakiness', the vibrations that reduce the effectiveness of hand-held binoculars if you are trying to resolve detail. When you pan slowly across the sky, the image moves smoothly with you. However, if you move quickly and come to an abrupt stop, there is a bit of a tendency for the image-stabilisation system to over compensate slightly before it settles down, but we did not find this to be irksome.

ALL PICTURES: @THESHED/PHOTOSTUDIO

Very good optics

The combination of excellent anti-reflective coatings on the lenses and Opticron's proprietary Oasis phase-coatings on the roof prisms helps the binoculars to transmit the full visible spectrum without the colour balance being affected by interference in the prisms. The result is faithful colour rendition and very good image contrast.

SCALE

Good IPD range

With the interpupillary distance (IPD) – the distance between the pupils of the eyes – ranging from 54–74mm, the Imagic IS 12x30s will suit a wide variety of faces. The 41.5mm diameter eye-cups mean there is 12.5mm between them at the minimum IPD, which should be sufficient for most people's nose bridges.

Internal focusing

The focusing mechanism works by moving an internal lens group. This has the advantage of eliminating a potentially 'rocky' eyepiece bridge that can compromise focusing if your eyes press on the eyepieces. It also makes it easier to prevent ingress of damaging moisture and dust.

FIRST LIGHT

Readily available batteries

The image stabilisation uses two AAA batteries (four are included), which have a specified life of 12 hours – but expect it to be less in cold weather. These are widely available, so you can easily source replacements but, if you can't, you can still use the 12x30 binoculars, albeit without stabilisation.

Anti-flip loop

The design of the 12x30 binoculars means that neck strap lugs at the eyepiece end of the body will be close to the centre of mass, leading to a tendency for them to flip horizontally through the strap. Opticron's simple and remarkably effective solution is a loop that pulls the straps together.

KIT TO ADD

1. 25mm bungee elastic and leather harness with quick release system

2. Opticron Pro Series lens cleaning set

3. Opticron Universal Tele-Adapter UTA 2x

▸ it snaps to a very crisp and obvious focus. The focus is very sharp across the central two thirds of the field of view, outside of which there is slight field curvature. Shining a bright light into the objective lenses demonstrates the effectiveness of the anti-reflective multi-coatings. There are baffles in the light path that control stray light extremely well and we were unable to induce spurious ghost images with a gibbous Moon in, or just outside, the field of view.

Flying colours

Colour correction and colour rendition are both good. False colour on high contrast objects is imperceptible at the centre of the field of view and is well-controlled over most of the rest of it, only becoming obtrusive towards the edge. Opticron advertises the Imagic IS as being suitable for lunar astronomy, and we could see no false colour at all on the terminator when it was in the middle of the field of view.

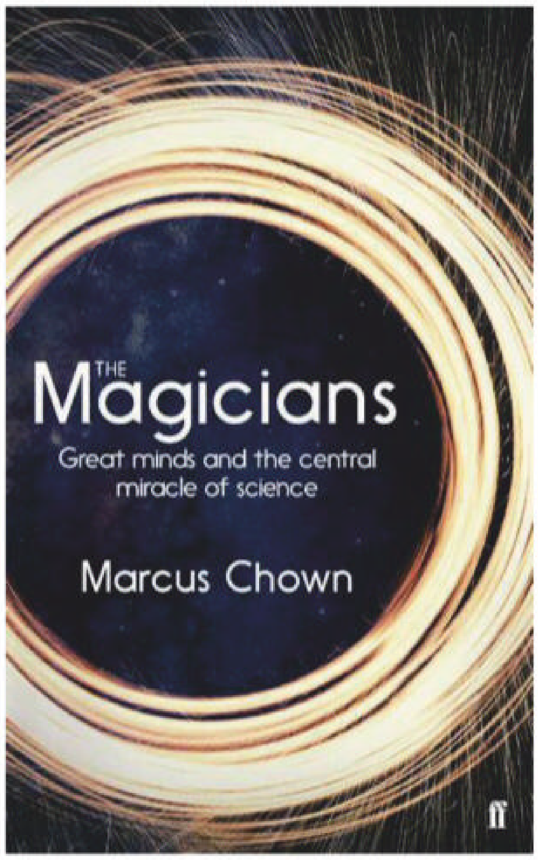
The light grasp of a 30mm aperture is obviously limited by the laws of optics, so this is not going to be a good choice for most deep-sky objects. That said, it is quite effective on some of the brighter ones. The open cluster M35 in Gemini initially appeared as a slightly granular glow with two stars resolved, but when we activated the image stabilisation (IS), six more stars appeared in and around this glow. It is also useful for splitting wide double stars. For example, we could not split 145 Canis Majoris (with a separation of 27 arcseconds) until we activated the image stabilisation, which proved just how important it is.

The new stabilisation system delivers well, making the Imagic IS 12x30s suitable for those who want small and lightweight multi-purpose image-stabilised binoculars. These will be useful for non-astronomical purposes and will occasionally complement your main astronomical observing equipment.

VERDICT

Build & design	★★★★★
Ease of Use	★★★★☆
Features	★★★★★
Image stabilisation	★★★★☆
Optics	★★★★☆
OVERALL	★★★★☆

BOOKS



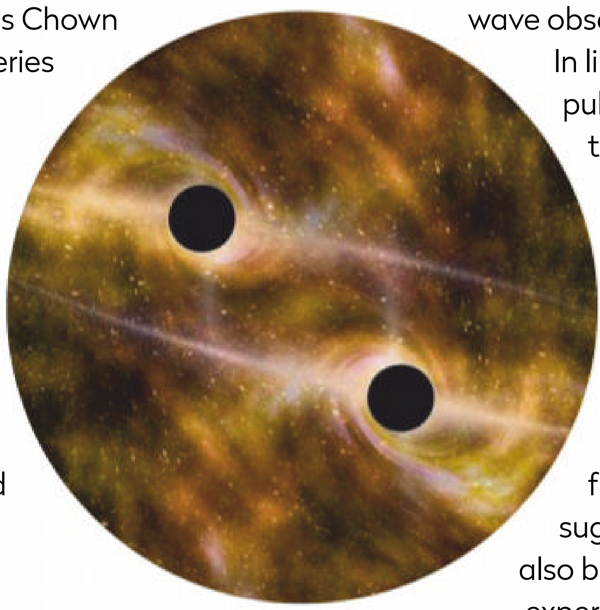
The Magicians

Marcus Chown
Faber & Faber
£14.99 ● HB

In his 14th book, Marcus Chown dramatises key discoveries in physics, explaining the science underpinning major revelations while incorporating fun, personal anecdotes about the key individuals involved.

From the link between electricity and magnetism to imaging the shadow of a black hole's event horizon, Chown explores the timeline of many fascinating phenomena in the Universe, from their theoretical prediction to their eventual confirmation through experiments.

One such was towards the end of the 18th century, when William Herschel doubled the size of the Solar System via his accidental discovery of Uranus using his garden telescope in the UK city of Bath.



▲ The force awakens: what happens when two black holes collide?

DES GREEN/ISTOCK/GETTY IMAGES

However, astronomers struggled to determine the orbit of the planet as it was never located where expected. In *The Magicians* we follow the story of French astronomer Urbain Le Verrier, who used mathematics to predict the existence of another planet, Neptune, which was causing Uranus to be in the 'wrong' place.

Moving to the modern era of astronomy, Chown explores the astonishing tale of how one prediction made by Einstein, which confirmed another of his predictions, was discovered by an instrument based upon yet another of his predictions. This may sound far-fetched, but it is the story of catching two black holes colliding and the subsequent release of gravitational waves. Predicted back in 1916 using his general theory of relativity, gravitational waves were described by Einstein as ripples in space and time, but he believed their detection would always be beyond our technological capabilities. It took almost 100 years but fortunately, in 2015, astronomers proved Einstein wrong on this last point and detected gravitational waves using laser-based gravitational-wave observatories.

In line with previous publications, this book is thoroughly enjoyable from start to finish and is a delight to read. It is well-suited to someone new to the field of physics and astronomy, but with several items for further reading suggested at the end, I also believe it will enthuse an expert. The only downside, is that *The Magicians* doesn't highlight a diverse group of scientists – for example, there is little focus on female figures – which is a shame. Nevertheless, Marcus Chown has done it again; this book is highly recommended. ★★★★★

***Amber Hornsby** is a postgraduate researcher at Cardiff University*

Interview with the author
Marcus Chown

Is there something innately different about the minds of scientists who make giant leaps?

I think you need a certain degree of mathematical aptitude because, for some reason we don't understand, the fundamental laws that orchestrate the Universe are mathematical. But, if you have such a mathematical aptitude, and years of training, the answer is yes.

What one discovery makes you think "I wish I'd thought of that"?

Antimatter. Imagine being Paul Dirac in 1928 and plucking from thin air – which is what he did – an equation describing an electron travelling close to the speed of light, and being gobsmacked to see that the machinery of the equation was duplicated. It also described a positively-charged electron, the first hint of a previously unsuspected universe of antimatter. And where would warp engines on the *Starship Enterprise* be without antimatter?

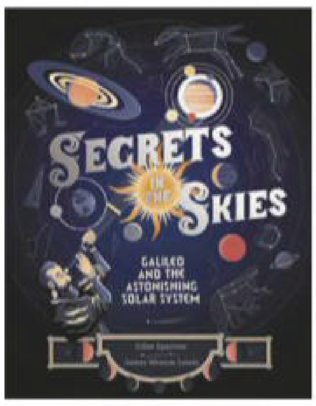
Which areas of science are most in need of breakthroughs?

The two towering achievements of 20th-century science are quantum theory – the theory of atoms and their constituents – and Einstein's general theory of relativity, which describes the large-scale Universe. We badly need to find a way to unite them, because in the Big Bang the large-scale Universe was small. Only if we can do this will we be able answer ultimate questions such as: what is space? what is time? what is the Universe, and where did it come from? To make progress, we definitely need another magician like Einstein, or preferably several – The Magicians!

***Marcus Chown** is a science writer and broadcaster*

Secrets in the Skies: Galileo and the Astonishing Solar System

Giles Sparrow, James Weston Lewis
Wren & Rook
£14.99 ● HB



Taking the story of Galileo Galilei to kids might be a tough call, but this book by Giles Sparrow and the illustrator James Weston Lewis manages it.

Sparrow's words tell the tale in simple language, but it's Weston Lewis's incredible artworks that elevate this book. You could just gaze at it. And I did. Page after page of gorgeous illustrations in a simple colour palette, in themselves reveal the story of the small boy from Pisa whose curiosity and inventiveness brought him fame, fortune – and a load of trouble when he grew up.

That said, the narrative and illustrations complement each other well. The text is clear and age-appropriate, while conveying historical and scientific complexities.

Secrets of the Skies explores humankind's enduring fascination with the stars; from ancient cave dwellers to Aristotle, Ptolemy, Copernicus, and Galileo – right up to the modern day.

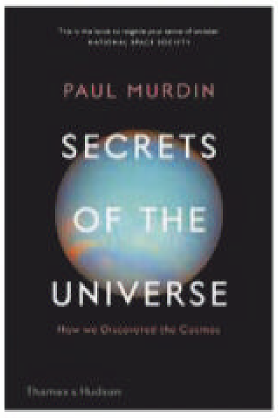
The artwork provides an epic feel, with scientific accuracy and notes of humour. But was that the Pope chucking Galileo's controversial tome (*Dialogue Concerning the Two Chief World Systems*) over his shoulder into a bin? I'm not sure 17th-century protestors outside Rome's Inquisition would have held placards saying "GAL-I-LAME-O", but I like it!

The inclusion of women and people of colour as those who followed in Galileo's footsteps, such as 18th-century African-American almanac-maker Benjamin Banneker, also provides a modern-eye on the history of astronomy. ★★★★

***Shaoni Bhattacharya** is a science writer and journalist*

Secrets of the Universe

Paul Murdin
Thames & Hudson
£10.99 ● PB



In *Secrets of the Universe* renowned astronomer Paul Murdin describes the fascinating story of realisation, discovery and exploration characterising humankind's relationship with the cosmos. In 65 short chapters, the author leads us at pace from prehistory to the cutting-edge of modern astrophysics in an accessible and enjoyable style.

There is no particular emphasis in this book and almost no area of astronomical knowledge has been excluded or brushed over. But Murdin's direct and concise style achieves something rarely found in a work with such a broad remit. While being consistent and fluid as a whole, each chapter equally serves as a perfect stand-alone essay. Readers will enjoy the ability to dip randomly into the book and take something away with them after only a few minutes.

Murdin seeks to provide the amateur reader with an accessible description of how astronomical knowledge has been obtained and to discuss its significance and consequences. The text is unencumbered by scientific jargon, while more arcane subjects are described with skill, patience and easy-to-follow language. One of this book's most admirable qualities is that it requires no prior knowledge of astronomy, only a desire for understanding.

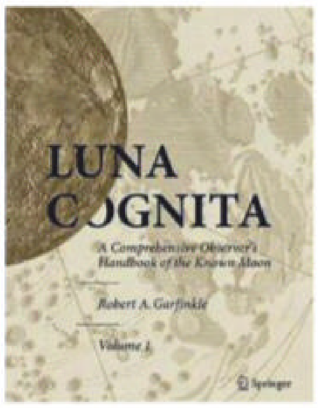
The text of *Secrets of the Universe* has been updated for re-publication a decade after its initial appearance. Then, as now, the book is to be highly recommended. Interested amateurs will get a great deal of enjoyment discovering the many fascinating revelations of astronomy throughout the ages. It's an excellent book to see the amateur astronomer through those cloudy nights. ★★★★★

***Alastair Gunn** is a radio astronomer at Jodrell Bank Observatory in Cheshire*

Luna Cognita

ESSENTIAL LUNAR REFERENCE

Robert A Garfinkle
Springer
£64.99 ● HB



At a whopping 1,737 pages, *Luna Cognita* ('known Moon') is not a light read, nor is it supposed to be. It is a comprehensive guide in three volumes, the type of which has not been published in such length for years.

Divided into three volumes and boasting over 1,000 illustrations, maps, charts and figures, *Luna Cognita* intertwines science, poetry, history and romanticism. Starting with an exploration into lunar lore and humanity's relationship with the Moon, Garfinkle then takes a detailed look at the Earth-Moon system and the morphology of the surface features. The 'General Selenographical Information' section is a joy and will excite astronomers and geologists everywhere.

The chapters of *Luna Cognita* on how to observe the Moon, the equipment to use and photographing its surface are thorough, but the level of detail could potentially be bewildering for total beginners.

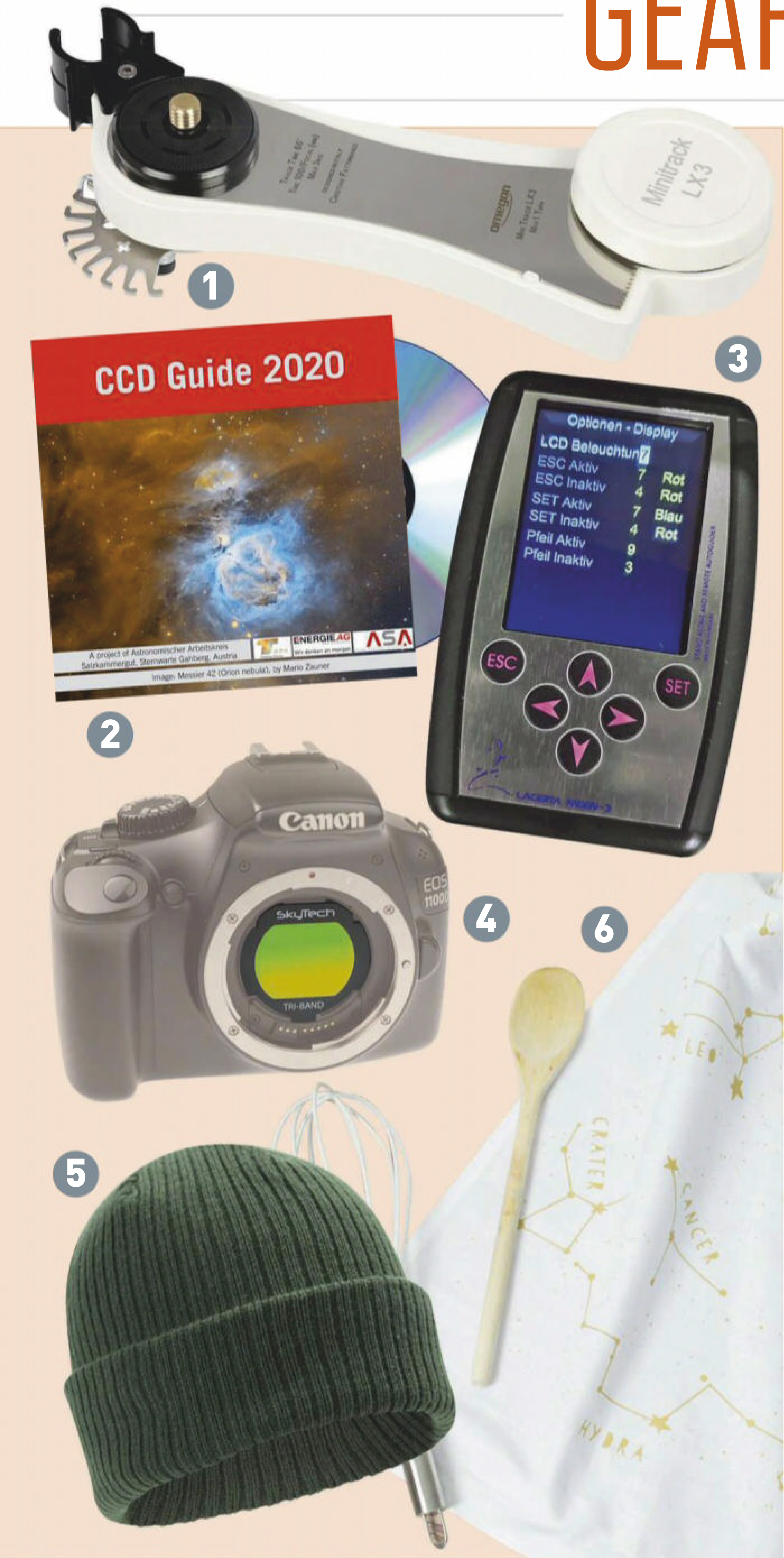
Perhaps most importantly, Garfinkle also encourages us to simply get outside and look up. The 22 chapters dedicated to crater-hopping throughout each lunar phase are a triumph, bringing together biographical information on whom each crater is named after, along with the coordinates and explanations of the morphology. He also introduces physical features and terminology that some may have never heard of, providing even more reasons to read this book.

In *Luna Cognita,* Garfinkle briefly mentions that there is no evidence of life on the Moon, but nevertheless still manages to bring our nearest neighbour alive on the page. This is an astonishing piece of work, 30 years in the making: an exceptional book that the writer should be very proud of. ★★★★★

***Katrin Raynor-Evans** is an amateur astronomer and librarian for Cardiff Astronomical Society*

Elizabeth Pearson rounds up the latest astronomical accessories

GEAR



1 Omegon Mount MiniTrack LX3

Price £165 • **Supplier** Modern Astronomy
Tel 020 8763 9953 • **www.modernastronomy.com**

Sick of juggling batteries to keep your mount powered? This portable lightweight tracker operates by clockwork – just pull the cord and you can track for up to 60 minutes. It supports up to 3kg of equipment.

2 CCD Guide 2020

Price €29 • **Supplier** Astro Systeme Austria
www.ccdguide.com

This CCD imaging guide comes with an extensive database of images and software to help you plan your imaging. The 2020 update includes more reference photos and improved tools to make planning your projects easier than ever.

3 Lacerta MGEN-3 stand-alone autoguider

Price £609 • **Supplier** 365astronomy
Tel 020 3384 5187 • **www.365astronomy.com**

Upgraded with self-learning adaptive guiding software, this version of the MGEN will help you keep your telescope on track. Comes with a colour screen for easy navigation and is powered by USB.

4 SkyTech TriBand Canon EOS clip-fit filter

Price £199 • **Supplier** Harrison Telescopes
Tel 01322 403407 • **www.harrisontelescopes.co.uk**

This clip filter fits directly into your DSLR camera, allowing you to focus in on the three main nebulae emission bands: Hydrogen-alpha, Hydrogen-beta and Oxygen III. This allows you to pull out the detail without the time-consuming task of taking multiple images.

5 Thinsulate knitted beanie

Price £3.99 • **Supplier** Mountain Warehouse
Tel 020 3828 7700 • **www.mountainwarehouse.com**

Double lined to keep the cold out and the heat in, this knitted hat will keep your head warm throughout the long nights. Stretches to fit most head sizes.

6 Constellation tea towel

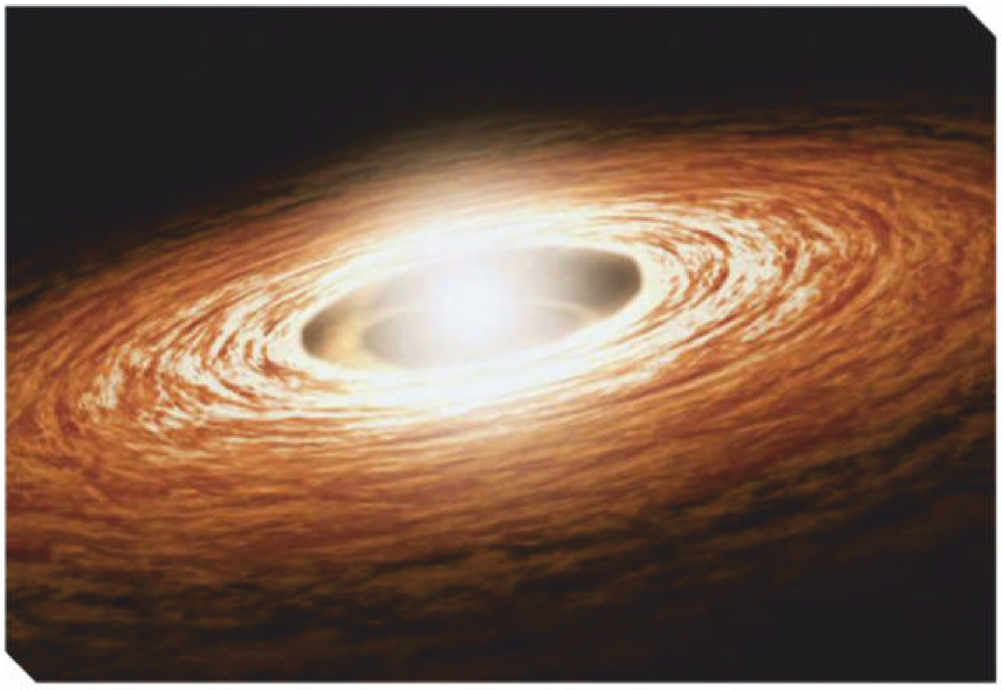
Price £12.50 • **Supplier** Newton and the Apple
http://newtonandtheapple.com

Let the cosmos help you with the dishes with this tea towel. Made from 100 per cent cotton, it is decorated with golden depictions of some of the northern sky's most famous constellations.

Shaoni Bhattacharya interviews Professor Maria Schönbächler

Q&A WITH A STARDUST SIFTER

A new analysis of stardust left over from the birth of the Solar System shines a high-precision light on Carl Sagan's aphorism 'We are made of star stuff'



▲ Scientists are looking for remnants of ancient red giant stars, which were present in the dust disc that formed at the start of our Solar System

What do you think happened at the birth of our Solar System?
Our proposal is that dust from dying stars travels in the interstellar medium, gets incorporated in a so-called molecular cloud which collapses and forms new stars like our Sun. Around the new star is a dust disc out of which terrestrial planets like Earth will form.

This means that there is stardust from red giant stars produced before our Solar System was created, that is still around today. We see that this dust was not completely mixed in our Solar System – there is still a gradient. Earth in fact has more of this red giant dust than Mars or the asteroids further from the Sun.

It's amazing that we can resolve this nowadays – for a long time we couldn't and assumed everything in the pre-Solar System was well mixed together.

How did you and your team examine the stardust composition of our Solar System?
We put our sample in a mass spectrometer and for each element in them we measured how many atoms of a specific weight (isotopes) there were. Doing this we were able to reveal the fingerprints of stardust in normal bulk material such as a rock, like a signature.

We looked at palladium isotopes in iron meteorites that come from asteroid samples. We had already done a similar study with zirconium isotopes, but to look at palladium we needed high precision measurements, which only became available recently.

What can looking at the stardust origins of Earth tell us?
What we and other researchers have discovered is that every planet or asteroid from which we have samples has its own isotopic signature. We also see that stardust has its own signature depending on if it is from specific stars, like red giants or supernovae.

In our study we found that Earth's palladium fingerprint – a specific enrichment of a certain palladium isotope – suggests there is more red giant material.

WORLD HISTORY ARCHIVE/ALAMY STOCK PHOTO

Maria Schönbächler is a professor of isotope geochemistry at ETH Zürich, Switzerland, and a senior author of a new study in *Nature Astronomy*

How do you know the chemical signatures of stardust from red giants?
You can predict with nuclear synthetic models which atoms will be produced in a red giant star.

You can also test actual stardust – some of it has survived in meteorites. It's very small – smaller than the diameter of a hair – really fine dust that you can extract and measure.

On Earth any original stardust has been destroyed because our whole planet was once molten, but there are a few very primitive asteroids where the stardust from before the planets formed has survived.

We know the dust must have been generated before our Sun formed. Our Solar System is 4.5 billion years old, and the stardust is ancient, from before that time.

What are the wider implications of your research?
When the planets formed the Sun was still quite hot and destroyed a lot of the grains that were not from red giants – those are very hard to destroy. Even though Earth is quite close to the Sun, the red giant stardust has survived better than other stardust as it is more robust at high temperatures.

In a previous study we analysed zirconium in meteorites from Mars in a previous study and saw that the red giant signature was not as strong. For our Solar System we can use this red giant signature as a tracer, as we know now that there was more of this stuff close to the Sun and less further out.

In the future we will be able to make models of how Earth and the planets formed based on asteroid material, as the asteroids are leftover planet building materials. It's a key part of the puzzle.

How does Carl Sagan's quote that "we are made of star stuff" stand up, what does your research add?
Well, it's correct! We are made of stardust and Earth has more red giant stardust than Mars. But our study also shows that much of this stardust was recycled many times before it was incorporated into Earth and eventually our bodies. What's more, not a great amount of stardust survived the Solar System's formation.

Telescope House
Telescope Specialists Since 1785
Web: www.telescopehouse.com
Email: sales@telescopehouse.com
Tel: 01342 837098
Sign Up
Explore Scientifc 127mm FCD100 Carbon Fibre Apo - £2287
Explore Scientific iEXOS-100 Wifi Mount £349
16MP - £842
1.7MP - £1256
7.1MP - £2099
Introducing the three new Explore Scientific Deep Sky Cameras - all simple to use One Shot Colour systems featuring 1.7, 7.1 and 16 Megapixel Sensors. These cameras all feature set-point cooling and come with control software and heavy duty storage & carry cases.
EXPLORE SCIENTIFIC
165mm & 152mm + Losmandy G11 PMC8 Mount Megadeals
Telescope House are pleased to bring you these two unique deals buy the extraordinary Explore Scientific 165mm or 152mm Apo Triplets together with the advanced Explore Scientific Losmandy G11 PMC8 Wireless Control Mount and make massive savings.
Explore Scientifc 99% Reflectivity Diagonal - £142
PMC EIGHT
PRECISION MOTION CONTROLLER
Explore Scientifc Maksutov Newtonian - £892
TeleVue
Browse the complete TeleVue eyepiece range on our website
Get organised with the Explore Scientifc Eyepiece & Accessory Bag- £25
NEW!
Introducing the Explore Scientifc 52-Degree Eyepiece Waterproof LER range From £59.99
NEW!
Bresser Astrophoto Tracking Mount From £265
The Bresser Astrophoto Tracking Mount is designed to be used with DSLRs and small telescopes for long duration astrophotography, providing a tracking platform to counteract the Earth's rotation and create wonderful wide field shots of the skies above us.
Available in head only and wedge tripod configurations.
Explore Scientific Sun Catcher Solar Filters From £18
HOT PRODUCT 2015 SKY
Lunt LS50 - From £1183
Excellent pressure-tuned portable Solar Scope
Explore Scientific Solarix Solar Film Filter £18
Lunt LS60 - From £1880
Excellent Value 100% Safe Solar Film. Ideal for DIY!
Lunt LS80/B1800 - £5214
Find the full range of ZWO Cameras at Telescope House From £151
Bresser Full HD USB Camera/ Eyepiece £50
Lunt LS100/ B1200 - £6478
ZWO ASIAIR Pro Wireless Scope control, Autoguiding & more. Arriving soon!
Website: www.telescopehouse.com
Email: sales@telescopehouse.com | For sales and advice call: 01342 837098
All prices correct at time of press. Subject to change. Errors and omissions excepted.

THE SOUTHERN HEMISPHERE

With Glenn Dawes

Discover an orange giant in Hydra, while Mars has close encounters with Jupiter and Saturn

When to use this chart

1 Mar at 24:00 AEDT (13:00 UT)
15 Mar at 23:00 AEDT (12:00 UT)
31 Mar at 22:00 AEDT (11:00 UT)

The chart accurately matches the sky on the dates and times shown for Sydney, Australia. The sky is different at other times as the stars crossing it set four minutes earlier each night.

MARCH HIGHLIGHTS

The eastern morning sky sees Jupiter under the Teapot of Sagittarius. As March opens, Mars is 10° above this gas giant (near the 'lid' star) with Saturn 9° below. Mars will have close encounters with both planets. On the 21st, the Red Planet will be 0.7° to the right of Jupiter. At month's end, Mars is 0.9° right of Saturn with both a similar brightness, although Mars will be visibly red. On the 19th, the crescent Moon will be 3° above Saturn with all four bodies fitting in an 8° circle – impressive!

STARS AND CONSTELLATIONS

The northern evening sky is home to one of the longest, but faintest constellations, Hydra, the Water Snake. Under light-polluted skies the only visible part is its brightest luminary, Alpha (α) Hydri or Alphard. This 2nd magnitude star (20° above Regulus) dominates an empty sky. Alphard is a giant orange star, something it has in common with Aldebaran and Arcturus (65 and 36 lightyears away). Being 177 lightyears distant, it would outshine both if placed at the same distance.

THE PLANETS

When it comes to naked-eye planets in the evening sky in March, brilliant Venus is in a class of its own, setting shortly after the end of twilight. Uranus spends the first half of the month within 8° of Venus, being closet at 2° on the 8th and 9th – a good binocular target. Turning to the morning, the dance of Jupiter, Saturn and Mars is impressive (see above). Mercury returns to the morning for a favourable apparition, visible just before dawn for most of March.

DEEP-SKY OBJECTS

We visit to two open star clusters in eastern Carina, a region blessed with many such objects. Commencing at the 3rd magnitude star, Lambda Centauri, head west 2°, crossing into Carina, to discover IC 2714 (RA 11h 17.4m, dec. –62° 44'). Through binoculars, this 8th magnitude cluster appears as a faint, hazy patch. Telescopes reveal dozens of stars of similar brightness (11th to 12th magnitude), spread across 15 arcminutes, many arranged in curved lines. On the southern edge is a distinctive 8th magnitude star.

Here's a challenge: from IC 2714 move 0.8° SSE to Melotte 105. In contrast to IC 2714, this cluster is faint and compact (only 4' across). Consisting of 13th to 14th magnitude stars, most instruments under 250mm show it as an unresolved 'cloud'. Patience and averted vision can help reveal some of the brightest members.

Chart key

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET
STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
URSA MAJOR
LYNX
CANES VENATICI
Cor Caroli
M63
M94
M106
LEO MINOR
GEMINI
Castor
Pollux
5th
COMA BERENICES
Sickle
CANCER
M44
M35
LEO
8th
Regulus
M64
M60
M87
M86
M65/66
M49
VIRGO
Procyon
CANIS MINOR
Betelgeuse
ORION
11th
SEXTANS
Celestial Equator
Rosette Nebula
Alphard
CORVUS
CRATER
M104
Spica
Ghost of Jupiter
M48
Winter Triangle
M50
MONOCEROS
M47
ANTLIA
M78
HYDRA
M68
PYXIS
PUPPIS
Sirius
M42
M83
M41
CANIS MAJOR
Rigel
VELA
Omega Cen
CENTAURUS
Eta Carina Nebula
LEPUS
CRUX
False Cross
Jewel Box
NGC 2516
CARINA
Canopus
COLUMBA
Acrux
IC 2714
Mel 105
Rigel Kent
Hadar
MUSCA
VOLANS
PICTOR
CIRCINUS
LMC
Gamma Normids Peak 14 March
CHAMAELEON
DORADO
ERIDANUS
TRIANGULUM AUSTRALE
MENSA
Tarantula Nebula
APUS
OCTANS
RETICULUM
HOROLOGIUM
Fornax A
ARA
South Celestial Pole
HYDRUS
SMC
PAVO
47 Tuc
Achernar
"Peacock Star"
TUCANA